

The AMSAT[®] Journal



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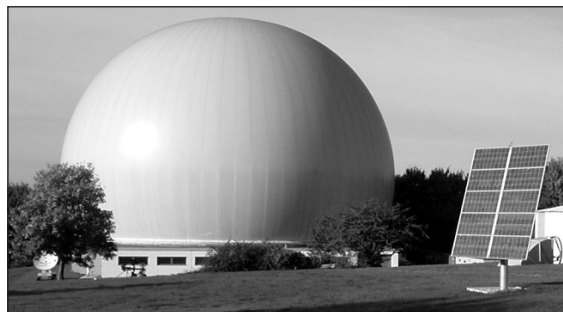
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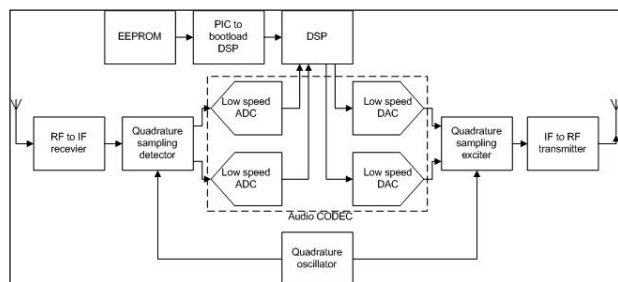
The Eagle Project

Antenna Control to the Max!



AMSAT holiday presents!

New! Engineering Notebook



AMSAT-NA
850 Sligo Avenue, Suite 600
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Periodicals

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and at additional
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How You Can Help Build New and Exciting Satellites

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US taxpayers should be able to avoid capital gains taxes on appreciated securities and receive a deduction for their fair market value.

Bequest

A codicil in your will, naming The Radio Amateur Satellite Corporation as a beneficiary will help insure the continuance of the Amateur Radio Satellite program.

Call the AMSAT-NA office at 301-589-6062 for questions on any or all of these ways you can help build new and exciting satellites.

Support AMSAT-NA

SSETI Express Comments from the AMSAT-UK Chairman

AMSAT Announcements

I am very sorry to learn of the problems with the SSETI power system and I hope that it may yet recover at some time in the future so that we will have the satisfaction of seeing all the hard work operational in orbit.

Nevertheless, a major element of the project has been successful - that is the training and inspiration of the students involved - and at least signals were heard from SSETI in orbit during the first day!

It was very apparent from the European Space Agency (ESA) and SSETI students that I met that they all greatly appreciated and admired the specialist experience and maturity that the AMSAT-UK members involved brought to the project - this has done much to raise the credibility of AMSAT within the ESA community. Well done!

We at Surrey have been through difficult times with our early spacecraft and so can empathise with the disappointment - however, I also urge patience and perseverance as we recovered two of our satellites after several months hard work when everyone else had given them up as lost!

SSTL is also pleased to have been able to assist the SSETI project by arranging the launch on Cosmos that successfully placed the satellite in orbit.

Best 73,
Martin, G3YJO ☸

AMSAT's Mission

AMSAT is a non-profit volunteer organization which designs, builds and operates experimental satellites and promotes space education. We work in partnership with government, industry, educational institutions and fellow Amateur Radio societies. We encourage technical and scientific innovation, and promote the training and development of skilled satellite and ground system designers and operators.

AMSAT's Vision

Our Vision is to deploy high earth orbit satellite systems that offer daily coverage by 2009 and continuous coverage by 2012. AMSAT will continue active participation in human space missions and support a stream of LEO satellites developed in cooperation with the educational community and other amateur satellite groups.





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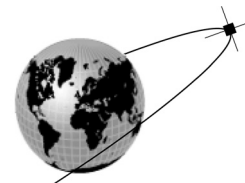
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APOGEE VIEW

by Rick Hambly, W2GPS • w2gps@amsat.org



This is an exciting time to be a member of AMSAT as we see the results of various projects around the world. We are ramping up our Eagle satellite design activities and continuing our work in support of the P3E satellite. This month I will give you a synopsis of some of the things that are happening while reminding you that we need your help to keep AMSAT healthy.

AMSAT's AO-51 Echo is performing very well and providing an interesting variety of operating modes. AMSAT India's new VO-52 Hamsat is also operating well and providing good service for hams around the world.

AMSAT-UK's XO-53 SSETI Express was launched in October. Shortly after launch SSETI deployed three CUBESAT pico-satellites developed by universities. Unfortunately, XO-53's batteries stopped charging and the spacecraft went silent, but the control team is hopeful that recovery will be possible. When XO-53 is recovered it will also function as an Amateur Radio transponder for the remainder of the mission. XO-53 will also downlink earth images and demonstrate technology for the European Student Earth Orbiter.

P3E

An AMSAT team headed by Bob McGwier, N4HY, is heading to Marburg, Germany in December to meet with the AMSAT-DL team to discuss the Software Defined Transponder (SDX) development and Internal Housekeeping Unit (IHU) hardware and software development. Bob will be involved in integrating the flight software.

Eagle

Since the Eagle meeting in Pittsburgh we have set up a Web-based project design tool called EaglePedia based on the same engine that drives the Internet Wikipedia project. This will provide a dynamic and organized way for the Eagle team to exchange ideas, drawings, software and design ideas for Eagle while providing a set of pages describing the current state of the project.

A meeting was held October in Colorado hosted by Bdale Garbee, KB0G, to work out a strawman proposal for placement of modules on the Eagle spacecraft and to define a strawman proposal for the Eagle wiring harness. Some other information was captured, including a proposed CAN-

Do! module address map, CAN-Do! timing analysis for Eagle and a list of issues identified during the creation of the strawman proposals.

Lyle Johnson, KK7P, attended an Actel conference regarding radiation-tolerant and radiation-hardened FPGAs for hi-rel space applications.

Spirited and very interesting discussions have been taking place on the subject of spacecraft power systems, including solar cells, batteries, power bus and battery charge regulators. Much of this discussion was prompted by the thought provoking proposals made by Lou McFadin, W5DID, at the Pittsburgh meeting.

There is an RF Meeting scheduled in a few days in Princeton, NJ hosted by AMSAT's new VP Engineering, Bob McGwier, N4HY. This promises to be an exciting meeting judging from the list of attendees including such dignitaries as AMSAT's Jan King, W3GEY/VK4GEY, who now lives in Queensland, Australia.

Other Satellite News

During the AMSAT-UK Colloquium in late July it was announced that it was expected that the PO-28 (PoSAT-1) satellite would be reconfigured for Amateur Radio use. Jim Heck, G3WGM, AMSAT-UK's Secretary, tells us "this is still the plan, but it is taking a little longer than expected to make the necessary non-technical arrangements."

SuitSat is just about ready for operation on 145.990 MHz. The Russian EVA that will deploy SuitSat, planned for December, has been delayed to late January or early February. According to AMSAT's VP Human Spaceflight, Frank Bauer, KA3HDO, "During this spacewalk, the ISS crew will push a Russian spacesuit overboard - with no humans in it, of course!" For more information on this unique mission see the AMSAT Web site.

How can you help?

To achieve AMSAT's goals we need new members, volunteers and money.

You can help by:

- Set up an AMSAT table at your local Hamfest.

continued on page 15 ...



AMSAT Eagle Update

James A. Sanford, PE, WB4GCS
Eagle Project Manager

Our Vision is to deploy high earth orbit satellite systems that offer daily coverage by 2009 and continuous coverage by 2012...



Greetings! Your Eagle team has been busy since my last report. Where to start . . .

First, we had a planning meeting which made great progress toward defining module placement and the wiring harness. The usual suspects (photo below) assembled in October at the home of Bdale Garbee in Black Forest, CO and developed a layout for the various payload and control modules and first definition of the wiring harness. This is a significant event for several reasons. First, this definition is the first step in articulating "what" Eagle will do in terms of "how" Eagle's pieces will do it. The various design teams now have their first definition of boundaries and interfaces. Second, this progress has generated quite a bit of enthusiasm among the team and has made it possible for us to demonstrate and test some parts of Eagle in the next year. We hope to demonstrate working transponders at Symposium in San Francisco. Figure 2 shows the current DRAFT layout of various components. Once we finish critiquing and revising the layout and harness it will be made available for your review on the AMSAT Web site.

In the meantime, you can read about the IHU at:

<http://www.amsat.org/amsat-new/eagle/IHU3/index.php>

You can read about the CAN-Do! Modules, our inter-module communications bus at:

<http://can-do.moraco.info/>

This technology will save us many wires, kilograms and tests. It has been proven in AO-40 and in many contemporary automobiles.



L to R: Lyle Johnson, Steve Moraco, Chuck Green and Bdale Garbee.

The payloads folks had a design meeting just after Thanksgiving to begin component level design of the RF package. This begins the transition of the block diagram to components and schematics which can be built and tested and then demonstrated for you.

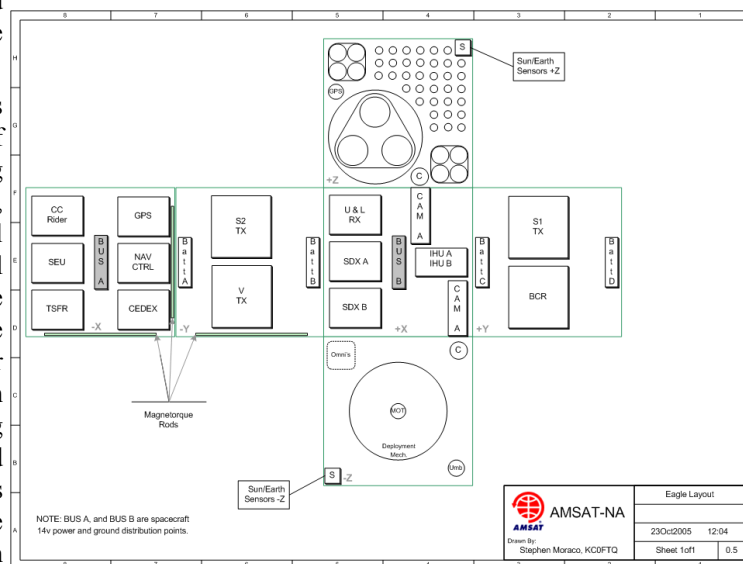
We have begun building engineering models of the payload modules and they will be measured and evaluated over the next few weeks.

While Eagle is taking advantage of the latest thinking and technologies, we are very well aware of historical failures. There has been intense discussion over the last month or so regarding failure modes and possibilities versus how to mitigate those failures. An easy answer is

redundancy. Yet, redundancy introduces complexity which introduces its own vulnerabilities. So, the question is, how do we design Eagle to minimize impact of any single failure? We also need to minimize impact of any common-mode failure, i.e., the same failure in many identical components. This is not a trivial issue and has generated some passionate discussions. This is a classic optimization problem and this discourse has been some of the most exciting and intellectually stimulating conversation that I've ever participated in. Here's the bottom line: your Eagle team is, early in the design stages, considering potential failures and how to design around them or deal with them. Our goal is to provide a long-lived, reliable, redundant platform.

Work on the CC-Rider package continues. See the article in this issue by Dr. Tom Clark, W3IWI, on this topic. One of the most exciting moments during the Eagle design meeting in Pittsburgh was the presentation regarding an affordable ground segment. As we promised long ago, the ground

segment will be developed along with the space segment so when Eagle flies, you will have or be able to obtain the hardware to exploit it. Digital voice communications from a handheld box and patch antenna is pretty exciting. I have dreamed for years of replacing hardline with CAT-5 all the way to a box at the antenna. CC-Rider shows great promise for delivering exactly that.



Here's the bad news. Eagle funds raised in the last month amount to ZERO. The ongoing efforts will soon exhaust all funds available to Eagle. Yet, \$2.00 per month per member will buy a spaceframe. You can extrapolate from there. We intend to build a model spaceframe in the next six months and may build several final spaceframes in the next year. (See the Vision Statement.) Eagle needs your help now. We need your contributions, and we need your recruiting effort. The latter is not hard. Last week at a very small hamfest, Kevin, N3HKQ, developed quite a bit of interest in AMSAT and Eagle and signed up or renewed a couple of members – at an event where we expected no interest. All it takes is a little effort. Help us deliver Eagle.

Your Eagle team is working hard, and we'll show you the fruits of our labors and your support in the next year. Thanks!

As always, comments and questions to: wb4gcs@amsat.org

73,
Jim



Logging in the Driveway Allen Kenny, KK4EMK, kk4emk@amsat.org

This article entitled "Logging in the Driveway" is NOT about cutting down trees. Nor is it about fencing in your driveway. It provides a solution to the problem of logging satellite contacts as you hold an HT radio in one hand and a directional antenna in the other.

Those of us who use an HT and Arrow antenna operate outside most of the time fighting heat, mosquitoes, cold and/or rain. We also do not have the advantage of using a real time computer logging program to record our QSO's. In fact it is difficult to even write down the calls we make - unless we have a third hand. Of course mounting the antenna on a tripod frees up one hand. However, that makes it difficult to move and twist the antenna for maximum signal and optimum polarity match. The solution many use is a voice recorder to register QSO's.

Digital Voice Recorder

Digital voice recorders available today have several nice features. These include capability to download audio files to a PC via a USB connection, precise time marks on the playback, ability to transfer accurate time from the PC to the recorder, and VOX capability to start/stop recording.



There are a couple of ways to use a voice recorder. The first is to record just your side of the QSO's you make. With a voice activated digital recorder, clip the mike near your neck, set the "VOX" level just right and you can record everything you say with very little dead air. After the pass, play back the recording and register the successful contacts in your official log.

I prefer a second method, which directly connects the audio output of the HT to the input of the recorder. This method records

everything you hear during the pass. If you are operating duplex, it also records your transmissions coming back down from the bird. Then play back the recording to verify the contacts (with grids) you thought you made. This can reduce busted calls. Listening to the calls you did not contact will make you better prepared next time. One drawback to this method is the VOX feature will not work because of the high noise level.

With some HT's you can use Radio Shack Y connectors and patch cords to connect the speaker output to both the recorder and a headset. However, for those of us using Kenwood HT's, the connection is not so straightforward. I initially used an old inductive telephone pick up coil attached to the speaker of the headset and plugged into the mike connection of the recorder. This worked fairly well but the connection was not reliable and volume was low.

Speaker Box

When I upgraded to the Heil Traveler headset, I immediately saw a better solution. The pictures show an inline speaker box made to plug between the headset and the Interface Adapter/Cable provided by Heil for connection to different model radios/HT's. Two stereo phone jacks bring the audio out for the recorder and for any additional headset(s) or speakers for observers to listen in during the pass. A patch cord with 1/8" phone plugs is used to connect the recorder to the box. The belt clip allows you to attach the box to your belt for a stable platform as you dance around the driveway to find the best antenna position.

The parts used were:

- 1 - 8-pin male connector (P700)
- 1 - 8-pin female connector (T700)
- 1 - 1" x 2" x 3" box
- 2 - 1/8" (3.5mm) 3 conductor stereo phone jack (RS 274-249)
- 1 - belt clip (borrowed from an old tape measure)
- 1 - # 6 - 32 x 1/2" FLAT head screw with 2 nuts (to mount the belt clip)
- As required - shielded cable and/or wire

I was not able to find a panel mounted female connector so I used a short piece of shielded cable and installed a cable mounted

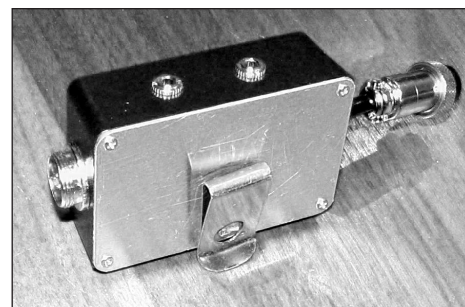
T700 connector. The two 8-pin connectors are wired straight through - pin to pin. Heil uses only 7 conductors to the headset. In the Kenwood HT interface application only 5 are required (pins 1, 5, 6, 7&8). The speaker connections (pins 6 & 8) are tapped out to the two phone jacks. Connect one of the speaker connections to both the tip and ring contacts of the stereo phone jacks to get audio to both sides of a stereo headset or stereo speaker system.

Operation

Before each pass, I remove the patch cord and directly record an info file with the satellite name, date, location, antenna, power, etc. The recorder has both a mic and a speaker jack in the top. I placed a piece of tape over the speaker jack to prevent reconnecting the patch cord to the wrong jack (again!!). Start the recorder when you first hear the satellite. If there is more than one satellite on the pass or you do both V/U bands on AO-51, key the band selector button several times in quick succession to put beeps on the recording to mark when satellites/bands are changed. The recorder generates RFI in the record mode. However, I get satisfactory results by carrying the recorder so my body is between it and the antenna.

The software that came with the recorder allows download and play back of the audio files with accurate time indication of each QSO. However, Audacity is a free software program that has many additional features including editing capabilities for saving just the good parts of the audio file. Audacity is available at <http://audacity.sourceforge.net>.

So the next time you answer a call from a handheld, think about us poor guys logging in the driveway (or wherever else we can find the sky clear of leafy trees). ☺



The "IOio" Antenna

by Juan A. Fernández Montaña, EA4CYQ, ea4cyq@amsat.org

Working with satellites under portable conditions is one of the most cheering experiences. It makes us forget our high performance fixed station and we feel excited when we manage to work, with an HT and a hand held antenna, other hams anywhere in the world.

All of us know that we can work satellites with an HT and a whip antenna, but when we tested the Arrow all of us discovered that we could work satellites without much difficulty. But if I have to set the antenna up and take it apart, I waste more time than a pass lasts. So, I decided to build an antenna which fulfils the requirements of having the elements in the same plane, while short enough to be kept in one or two pieces hung from the car's trunk cover and with enough gain to work satellites comfortably.



The IOio antenna hung under the trunk lid.

I took advantage of having built and enjoyed K5OE's (Jerry's) designs, TPMII and Eggbeater II, so if we bear in mind that we don't need circular polarization to work in portable conditions, I created the prototype that you can see in the photos, which is about 1 meter long.

Testing this antenna design with an MFJ259-B antenna analyzer, it shows an impedance between 40Ω and 75Ω along the ham bands so the SWR is between 1.3:1 and 1.9:1. This



The IOio antenna ready to be put away.

interesting piece of information reveals we can transmit without problems and it is not worth making life difficult to correct for this SWR. Furthermore the antenna will be simpler to build.

To test its terrestrial communication performance I compared it with an original Arrow. This antenna was able to produce stronger signals in the VHF band and is a little worse on UHF. After all, these are reasonable results because Arrow uses 3 elements on VHF and 7 on UHF.

One Sunday, I got up with the intention of carrying out a real test and I took my THD7 in my left hand and my new antenna in the right. I worked through AO-27 (PD5DJ, EA7FZS, EA7GO), AO-51 (DG9YIB, DJ1KM, EB4DEH) and SO-50 (SP7THR, OO7EQ). I tried reducing my power output and the birds always received my signals, even down to only 50mW; even AO-51. It was an amazing experience to hear myself under these conditions. My friend Pedro, EB4DKA, has tested it through FO-29 with a TM-255 and THF7 and obtained excellent results.



My niece, Sonia, holding the IOio antenna.

In summary, using this antenna in portable conditions with an HT, with its high gain in VHF, lets us work the satellites without difficulty and it has enough gain on UHF to make reception of satellites from AOS to LOS very easy. Furthermore we don't have to waste time to set it up; only take it out of the car, plug in the antenna connector and push the PTT. I'll never again feel too lazy to work satellites.

Some of my ham friends asked me to describe the antenna and it was difficult for me to explain it. I dared to name it "IOio", so the name describes its shape.

You can find more building details, experiences, audio recorders and much more in a corner of Pedro's Web site at: <http://miguel.servihosting.com/eb4dka>. My e-mail address is above.

I am looking forward to reading your comments! ☺



My niece, Ursula, aiming the IOio antenna.



Detail of the duplexer.

Supporting AMSAT's Vision - Make a Donation

Barry Baines, WD4ASW, wd4asw@amsat.org

VP-Marketing & User Services

By the time this issue of *The AMSAT Journal* has arrived at your door, you should have received an envelope from AMSAT that contains a letter from AMSAT President Rick Hambly, W2GPS, as well as a brochure on Eagle and a donation form. A return envelope is also included. This package of materials represents the start of a major fundraising effort to support AMSAT-NA's commitment of fulfilling the key milestone of our strategic vision: "To deploy high earth orbit satellite systems that will offer daily coverage by 2009 and continuous coverage by 2012."

Included in the package is a new brochure on Eagle that summarizes the key features of our new satellite design and addresses the reasons why we're building the Eagle-class of satellites. The brochure was developed by AMSAT member Deanne Lutz, K7DID, with input from a variety of AMSAT members. Along with educating our membership on Eagle, the brochure will also be used as a handout at hamfests, club presentations and other functions where AMSAT may be in position to highlight Eagle and encourage others to donate in support of this project. To my knowledge, this is the first time that we've formally printed an informational brochure on an ongoing AMSAT satellite development project.

The drawings within the brochure highlight the fact that Eagle is indeed 'for real' and as we approach 2006, much work has been done to date. Hopefully the brochure will help you to gain a better appreciation of what the Eagle project is all about and learn what the key features of the satellite will be. Suffice it to say that I am very excited about Eagle and I left the Eagle Team Meeting in Pittsburgh this past October extremely impressed by both the technical accomplishments to date and the future direction that the Team is taking to make Eagle a technical success.

While our Eagle Team continues with their efforts to design and build Eagle, this is the time for our membership to step behind the effort and provide the financial support necessary to make this vision a reality. With the holiday season and the end-of-year approaching, now is an excellent time to make your donation in support of the Eagle.

For US citizens here are some thoughts about donations that are not included in the Eagle

appeal that you recently received:

- Donations made prior to December 31, 2005 may be applied against your 2005 income tax return. Donations can help you avoid unnecessary taxes while you benefit AMSAT. Make a cash donation to AMSAT **NOW** and take full advantage of the donation in the current year and have the heartfelt satisfaction from giving that goes with the holiday season.



AMSAT's brochure highlights Eagle, a satellite that will only be achieved if YOU generously support it.

- Consider donating marketable securities (stock) to AMSAT prior to end-of-year. If the stock has depreciated in value, sell it and deduct the loss. Then donate the cash received from its sale to AMSAT. You end up with a double deduction.
- If the stock has appreciated in value, do not sell it but transfer it to AMSAT as a gift. Then AMSAT will sell it and you will avoid all the capital gains tax you would have paid had you sold it yourself. Your gift will be deductible at its full market value on its date of delivery to AMSAT.

- Consult your Tax Advisor concerning the potential benefits of donating marketable securities to AMSAT. Should you have securities that you would like to donate to AMSAT, please contact AMSAT Treasurer Gunther Meisse, W8GSM, for details on how to make the transfer. Be sure to allow sufficient time for the transaction to be completed prior to December 31 to deduct your donation in 2005.
- Consider longer range giving strategies in support of AMSAT's annual fund raising requirements for Eagle in 2006-2012. Just as colleges and other educational institutions have multi-year capital campaigns in support of a building program or other major goal, AMSAT is now embarked on a multi-year capital campaign to gain the funds needed for launching two satellites. To succeed, AMSAT must count on its membership to specifically support Eagle annually for the next six years. Now is a good time to consider AMSAT in your future donation plans.
- Consider making a bequest to AMSAT in your will or include AMSAT in your estate planning. Consult your financial planner about how you might include AMSAT in the distribution of your estate since one way to reduce estate taxes is to make a charitable donation at death. The estate of a person who leaves assets to AMSAT is reduced by the amount actually being transferred to AMSAT. The transfer is often achieved by a bequest provision in the will, but the transfer can also be made by other means, such as a lifetime trust provision. Consult with your advisor on how you can help AMSAT in the future upon your death.

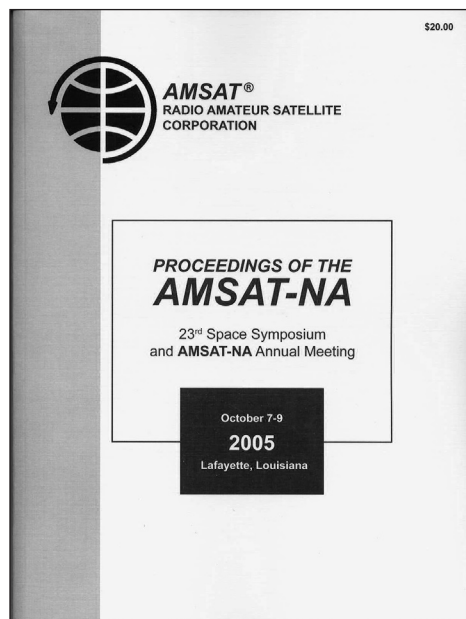
Please keep in mind that donations above \$120.00 qualify for President's Club status where you may elect to have your donation spread over twelve months using your credit card as well as receive a special President's Club pin in recognition of your support of Eagle.

AMSAT can only achieve our vision if the membership enthusiastically supports Eagle financially. As an AMSAT member, you can help to make a difference regarding Amateur Radio in space by actively supporting Eagle. **Help Hatch Eagle!** 🐣



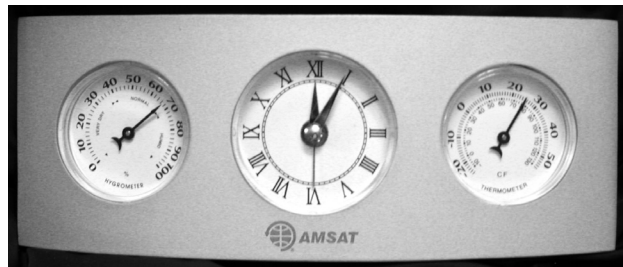
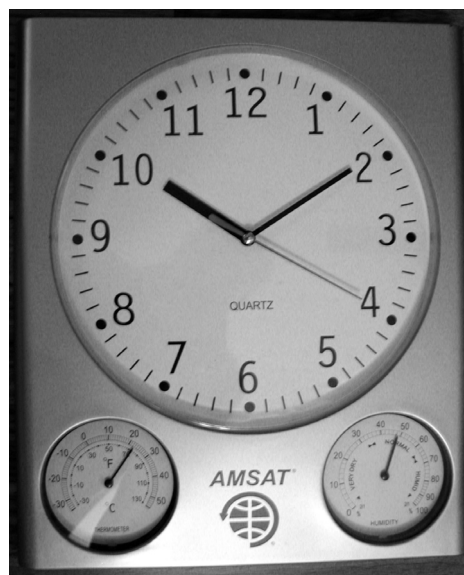
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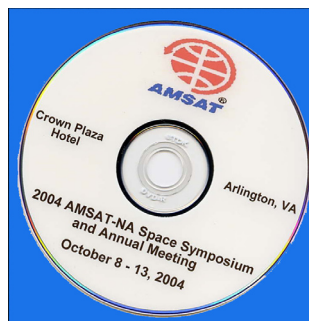
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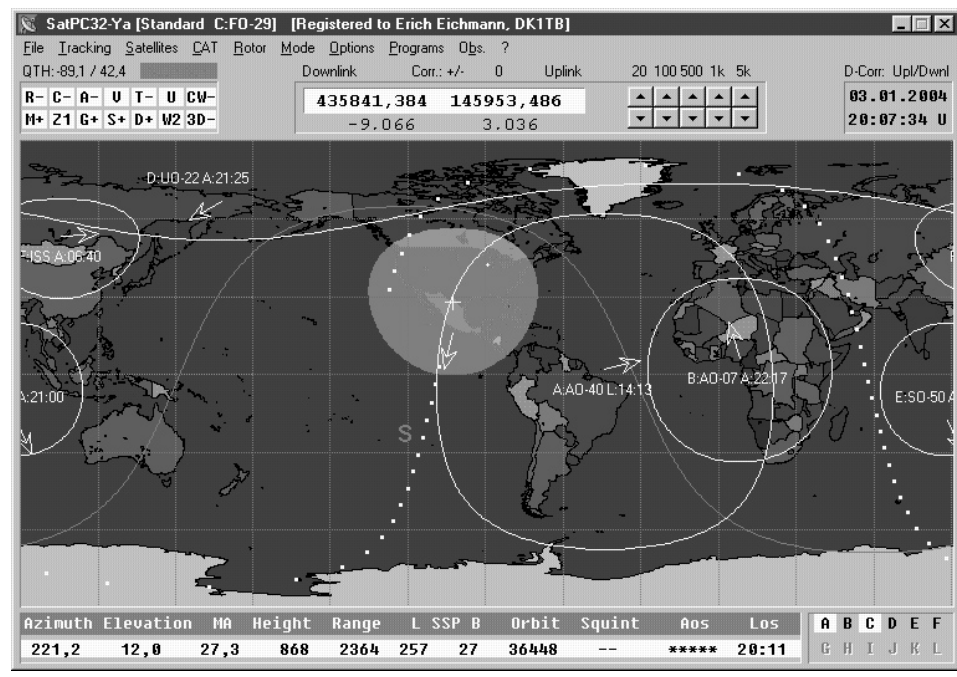
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The author DK1TB donated SatPC32 to AMSAT. All proceeds support AMSAT.



Engineering Notebook

Bob McGwier, N4HY, n4hy@amsat.org
AMSAT Vice President for Engineering

At the October 2005 meeting of the AMSAT board of directors in Pittsburgh, I was asked to be the AMSAT V.P. Engineering. Stan Wood is extremely busy with business commitments with an onerous work schedule. Jan King has moved to Australia. When Rick asked for any volunteers to take a step forward, I was talking as usual, missed my cue, and everyone else stepped backwards!

All kidding aside, I have been on a 14-year hiatus from the AMSAT "tech group". It is hard to believe it has actually been that long, but those are the facts. I was Assistant VP Engineering to W3GEY, and member of the board when I chose not to run again and then left Amateur Radio behind for those years. I have led an amazing life in those 14 years. N2HPE still puts up with me (a great spouse is often the hardest thing to explain and I am just grateful). My three children are great and my youngest mostly leaves the nest after this year when she goes off to college. I seem to have more time for Amateur Radio. My job, which during these fourteen years involved travel all over the place and long extended absences, changed character two years ago.

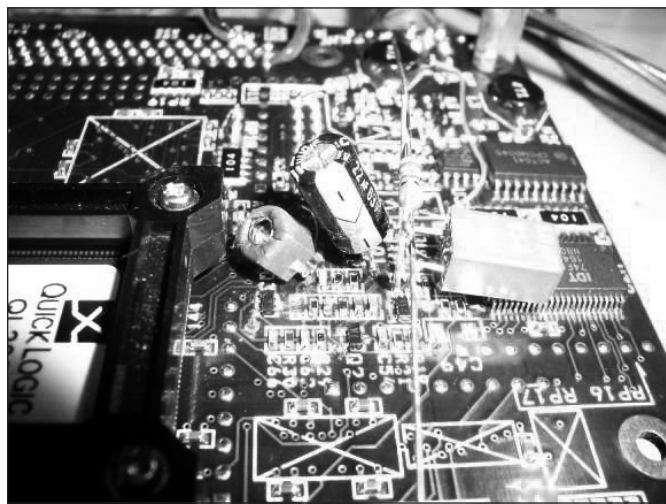


Figure 1: IHU prototype, some assembly required!

SDR Anyone?

Gerald Youngblood, K5SDR, AMSAT member and owner of Flex Radio, wrote a series of QEX articles (please visit <http://www.flex-radio.com> and click on the articles button on the left) on a thing called a software defined radio. GnuRadio (<http://www.gnu.org/software/gnuradio/>) takes a different approach to the software defined

radio and one that is to be highly relevant to the Eagle spacecraft. Tom Clark, W3IWI, proposed CC Rider. It would be the vehicle to deliver the Phil Karn dream of a serious digital mode on an AMSAT spacecraft and could be a really major resource for amateur satellite enthusiasts in particular and Amateur Radio in general.

Invited to the Orlando Eagle design meeting, I rejoined the AMSAT technical ranks. AMSAT is a meritocracy. If you have merit, we will use you until you run dry, so listen to my story and beware! There was the usual discussion going on about flying Mode B versus not flying Mode B. Phil Karn is arguing that no satellite is interesting if it does only SSB. The people who have to garner your \$upport to help pay for it immediately argued that they are elected by the members who want Mode B or Mode U/L/S and linear transponders. I suggested that it would very interesting indeed if we flew Mode B, Mode LS, etc. as software defined transponders and could change the character of the transponders on the fly. I was the immediate owner of this since I opened my mouth. I am sure you will find we are going to provide you a great

satellite with these newer technologies and approach to an AMSAT transponder in the Phase 3 Express and Eagle spacecraft. Both Phase 3 Express and Eagle are much simpler systems that AO-40 and this has a lot to recommend it from both the engineering and organizational sides of these projects.

Herr Doktor Meinzer Calls

Earlier this year, a group of AMSAT-NA members were invited to go to Marburg, Germany to

participate in the Phase 3 Express satellite design meeting dealing with the integrated housekeeping unit, the spacecraft main computer. You may see the current details for the spacecraft computer on the AMSAT Web site. The spacecraft control mechanism is based on an automobile industry control device called a Can controller. Stephen Moraco, KC0FTQ, and Bdale Garbee, KB0G,

have really done a great job and Moraco has provided us with a well documented piece of the electronics for our spacecraft See <http://can-do.moraco.info>

Chuck and Lyle, with some design work from Karl, designed and assembled the IHU-3. As with all AMSAT computers, it comes with some assembly required! As you can see in Figure 1, we are always tweaking the prototypes. This was "Karl's nightmare". There was a problem with the PLL circuit on the oscillator, Karl went away for the evening and the next morning came



Figure 2: L-R WA7GXD, KB0G, KC0FTQ, DG2CV, N4HY and DJ4ZC at IHU meeting in Marburg.

back with the answer! A few parts later and the IHU worked as promised. While we were there we signed on to do the software defined telecommand link for P3E and P5A. Stephen Moraco and Bdale Garbee continue their excellent work on the control bus for the spacecraft, which is built around a CAN module. Please visit Stephen's Web site to see the fantastic work.

The IHU-3 will use the ARM7TDMI chip. Many of your cellular telephones, MP3 players, PDA's will have this chip in it. There is a very robust software/hardware watchdog clock that will reset the system if the software fails badly. During the summer, we got an IPS load module written and running. We have loaded the base IPS (IPS-E0) and the assembler as well and programs have been written in IPS and tested. IPS is the "Forth like" language developed by Karl specifically for small computer control systems. With its RPN (reverse Polish notation) based approach, it is ideal for small spacecraft housekeeping tasks. The IHU-3 will do a software defined radio modem for the telecommand receiver. We will be testing an encoding scheme which should enable us to communicate with the AMSAT-DL





Figure 3: Chuck Green, N0ADI, Frank Sperber, DL6DBN, and the boss; Heike Straube, P3E Project Manager.

dream, P5A, an Amateur Radio spacecraft to orbit Mars!

Software Defined WHAT?

From my first paragraphs you can see that software defined radio has drawn me back to Amateur Radio in a way that I believed was no longer possible. But in fact, it gives your 'techie crew' a way to make the Mode B, Mode U/S and Mode L/S transponders something really interesting to themselves. In Orlando in 2004, we saw it as a solution to our increasing boredom with doing the same thing again. You will definitely benefit from this and I wish to demonstrate how with a few words and pictures.

This past summer at the Surrey satellite

symposium, Howard Long, G6LVB, gave a talk, showed software, and demonstrated his STELLA system. STELLA is just an acronym for Satellite Transponder with Equalizing Level Limiting Adaptor. This is really just a working super Leila on very good steroids! Howard has demonstrated a piece of code that will limit every signal above the noise floor of the transponder to a few dB above the beacon and it will do this modulation of the passband signals without undue distortion.

Howard chose to use the approach that Flex Radio has used in the SDR-1000. The main features are that you get a very high performance mixer, with excellent image rejection (easily tunable to improve) in very few parts and with an overall win in transponder performance due to no longer needing very hard to find filters.

Lyle Johnson and Chuck Green have agreed to take on the task of getting SDX prototype hardware built. Howard has agreed to lead the software effort with help from Frank Brickley, AB2KT, and me. Frank, Lyle,

Howard and I will be traveling to Marburg to see if the software defined transponder can be fit into the P3E frame but then only if it can be fit into the P3E schedule!

The software defined transponder will allow us to do some very neat things. We will be able to divide the transponder up into digital, analog, FM, etc. pieces. The extremely high performance of the mixer design will allow us to do this with very low intermod and give us a very interesting set of experiments.

That is enough for this issue. Please expect to see the Engineering Notebook in every issue. In future editions of the *Journal*, I will discuss more current issues, including Phase 3E, CC Rider, new battery technologies, and more. 🌐

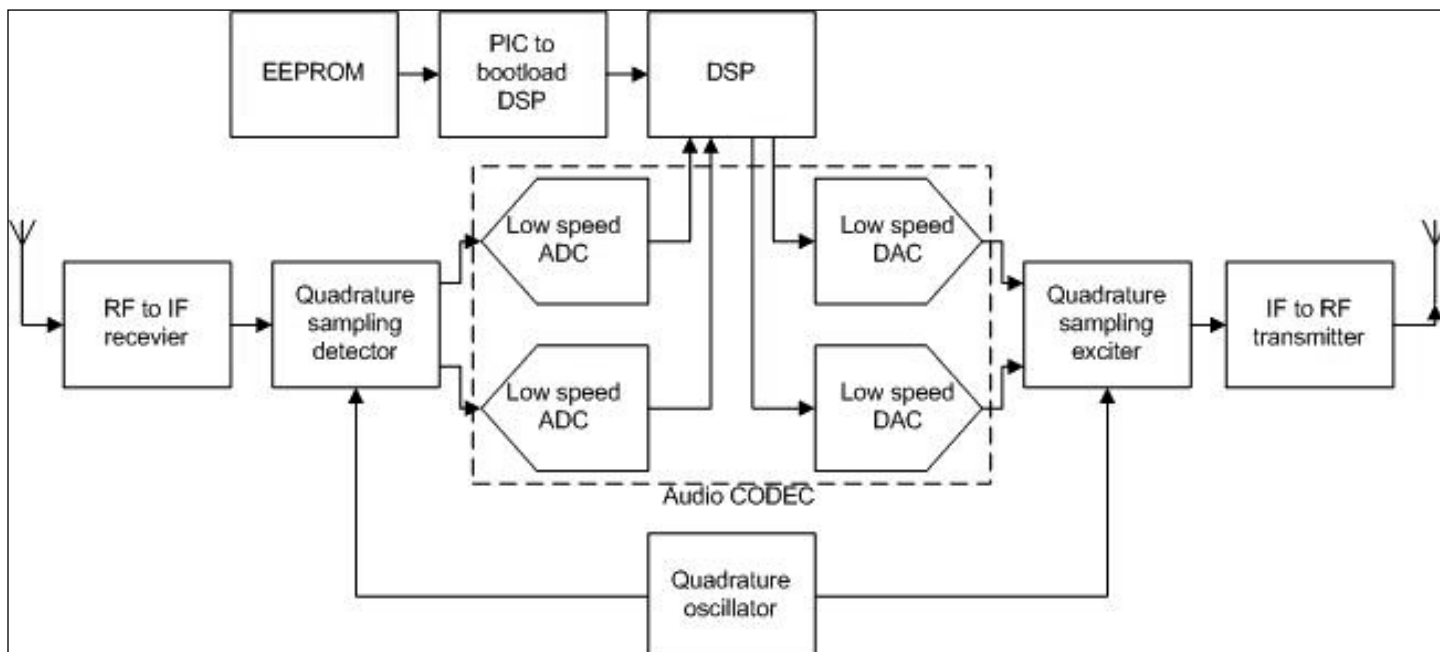


Figure 4: Howard Long's Block diagram of a Software Defined Transponder.



Update on SSETI Express – OSCAR 53 – November 2005

by Graham Shirville, G3VZV

As has been already reported, SSETI Express, XO-53 and eight other payloads successfully lifted off from Plesetsk in Northern Russia at 06:26 UTC on October 27th.

The satellite was designed to wait for some time after separation from the launch adaptor before activating any electrical circuits and exactly at the appointed moment, 08:33 UTC, UHF signals were heard at the ground station at Aalborg in Denmark and also by the launch team in Plesetsk (with a THF7 and a handheld Arrow antenna!)

On the first pass good telemetry was received and simple commanding from the ground was successfully tested. Just a few minutes later we even had an e-mail from NORAD with some preliminary Two Line Elements which indicated that satellites had reached the correct orbit.

Subsequent orbits produced equally good signals but also showed that the battery volts were decreasing rapidly – it seemed that no charge was reaching them from the solar array.

Sadly it appears that, although the satellite was commanded to reduce power consumption to the minimum, the battery was finally depleted around midnight and no further signals have been heard from it since.

A Failure Analysis Team was immediately assembled at Aalborg as that was where most of the Express team members had already gathered. Their initial report has been prepared but not yet finalized. It seems likely that a device in the battery charge regulator system has failed and it is this that may be preventing the proper charging of the battery. It has also been determined that there is a finite possibility that the fault may “self heal” and that XO-53 could therefore recommence operations at some time in the future.

The final report is expected to be available during December and the results published here as soon as possible.

It was not possible to activate the S-band transmitter before the battery became depleted so we may never know how it survived the launch. In many ways however the mission has already been a success for SSETI itself as it demonstrated that it is possible for a group of university students to design and assemble a full size satellite in a short time and place it into space.

It has also been the opportunity for the radio amateur world to demonstrate their ability and willingness to create a worldwide network of groundstations – this is something that cost the professionals millions of pounds or dollars or euros each year. This demonstration will stand us in very good stead for the possibilities of being involved in future similar missions.

It has also demonstrated that radio amateurs and students can share their passions and skills to great effect in the space world!

I would like to pay a tribute to my colleagues in the AMSAT-UK Express team of Sam Jewell, G4DDK, David Bowman, G0MRF, Howard Long, G6LVB, and Jason Flynn, G7OCD. Their contributions not only to the S-band unit but also to many other facets of the satellite were respected as invaluable.

Also to Charlie Suckling, G3WDG, who provided another 3 watt S-band PA (his first one is providing beautiful signals on AO-51), to Richard Limebear, G3RWL, who put together the Express Handbook, to the Polish team at the University of Wroclaw for providing the S-band antennas, the power splitter and beautiful enclosure, and to Jean-Louis Rault, F6AGR, from AMSAT-F who arranged the proper ITU registration and notification for the satellite in the Amateur Satellite Service.

In any event, the success of our working arrangements with the other Express teams was down to the great skills of the project manager - Neil Melville. Neil spent literally thousands of hours on the project working directly with a variety of teams around Europe to ensure that the satellite was ready for the launch. In the process all the groups have learned a tremendous amount about building satellites and working as a team. Many valuable lessons have been learned and documented.

Although this project was not expensive in monetary terms for AMSAT-UK, (the costs of components charged to our funds were less than £1500) the level of support it has received from hundreds of amateurs around the world has been immense and this visible support has been impressing the other Express teams for many months.

It appears that well over 1000 amateurs downloaded the SERACC client software, a similar number the Express Handbook which was made available in three languages, and over 500 downloaded the Integration and Launch campaign logbooks.

Hopefully further opportunities for cooperation between radio amateurs and similar projects will be developed in the future. I believe that the SSETI Express mission has laid down great foundations for this to occur. ☺

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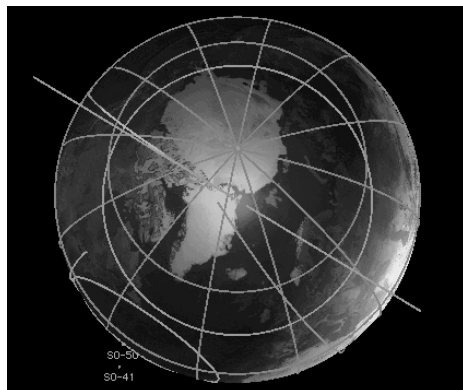
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THANK YOU!



First of all, I have to apologize for the little information about the P3-E progress over the last few months. Indeed, I gave an update during the recent AMSAT-UK Colloquium and also our AMSAT-DL magazine has a lot of information, which will be reprinted in the AMSAT-NA Journal and other sources with some delay. To improve communications with our membership and worldwide audience, we decided last year to improve the information flow on our Web site using a new content management system (CMS, Mambo). Unfortunately this took much longer than anticipated, but the new portal should be available to the public by December. The CMS itself is almost fully functional, but we have to transfer and re-edit all the information from our old Web site. You can probably imagine, that this is still a lot of work. However, once it is running, we hope to put more information on-line and also have a news section with more regular updates. Indeed, because of this, we almost stopped updating the old Web site.

So far, AMSAT P3-E is making good progress, but slowly. Some modules have already arrived in Marburg for the integration, but other module builders make good use of the additional time due to the yet unknown launch date, which sometimes makes it also hard to motivate people. The wiring harness is defined and will be built and integrated into the S/C soon. Thanks to the CAN-bus and our CAN-DO module controllers, it will be not such a big beast as on previous P3 satellites. Talking about the CAN-DO, another radiation testing was performed. This time irradiation with protons. The CAN-DO module and other selected electronic components for P3-E and P5-A were exposed to protons with an energy of 60 MeV. The CAN-DO module stopped operating at 61 krad, which is good for a projected mission duration of more than 10 years. Since the CAN-DO module is one of the most critical parts on P3-E and P5-A this gives us a better feeling that it should not suffer from a radiation induced failure. Very good progress was also reported from the development teams of the new IHU-3, both in terms of hardware and software. While a big step forward was made, the full integration and testing of the operational IPS software and all it's functionality (including the turbo codes and software defined modems) is next. Within the next couple of weeks, a radiation testing is also

planned for the IHU-3. In addition to the analog transponders flying on P3-E, we will also look into the possibility of having an SDT (Software Defined Transponder) flying on P3-E for the first time. The recent developments on Software Defined Radio technologies and STELLA, as reported in this *Journal*, might give us completely new ideas. While this is quite late and various details must still be discussed, the necessary RF interfaces are already available in the module space we have identified for this. Expect to hear more about this in the next few weeks.

As mentioned before, an extremely critical step was taken a few days ago when Ariane 5 scored a double success for Arianespace with the successful launch of Syracuse 3A and Galaxy 15 on-board flight V168.

While we do not yet have an official launch manifest, we are in full contact with our partners at Arianespace. Everyone is working hard to find a suitable slot for P3-E to the benefit of both sides. While the year 2005 is almost over our target to get P3-E into orbit is still 2006 and will remain so. Clearly, the continuing success of the new Ariane 5 will help us too. Initial arrangements for environmental testing, including vibration and thermal vacuum testing are already made.

Indeed, we still need a lot of support for P3-E and also donations. But with all the contributions we are receiving, P3-E will be truly another international satellite. I'm in particular delighted that AMSAT-NA joined and supports the P3-E project. We have excellent personal relationships between our organizations and apart from the fun, things are developing really well to the benefit of EAGLE, P3-E and all the projects on the horizon.

Best wishes,

Peter Guelzow, DB2OS
President AMSAT-DL
P3-E Project Leader



Apogee View continued from page 3 ...

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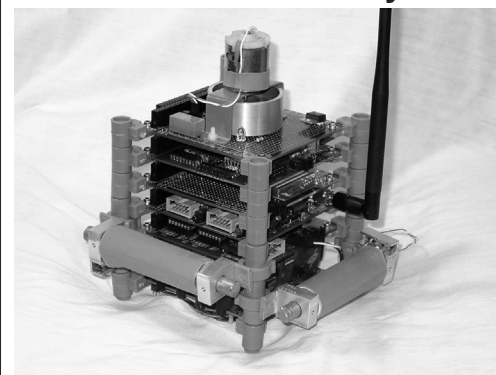
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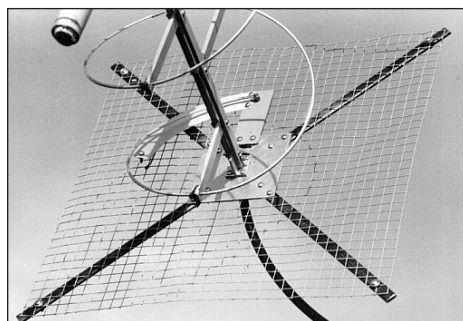


The Development of a Quarter Wave Match for Helix Antennas

by Clare Fowler, VE3NPC, ve3npc@amsat.org

Back in the days of Oscar 10 when I first got on satellites, I constructed helix antennas for the 70 cm uplink. I followed the design in the *Satellite Experimenter's Handbook*. The boom was a fiber glassed 1 x 2 pine board. I did not like the idea of using heavy gauge copper wire, copper tubing or coax for the conductor as they result in a very heavy antenna. To handle an array of four antennas you would almost need a gun turret to rotate them. So I used aluminum ground wire from the local radio store for the conductor. It is readily available, inexpensive, light weight and durable. However it has a couple of drawbacks. Soldering aluminum wire to a type N connector is something not easily done. I got around this problem by flattening the last 3/8 inch of the aluminum wire with a hammer on an anvil and drilling a hole in the center to clear a 4/40 screw. The head was cut off of a 1/2 inch 4/40 brass screw. One end was ground down and soldered into the pin of the N chassis connector. The end of the aluminum wire with the hole was held in place with a brass nut.

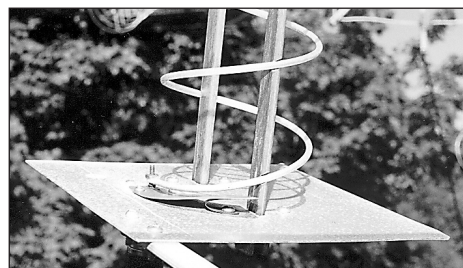
The other problem is the matching section on the first quarter turn. The conventional method is to fasten a fin to the first quarter turn. I did this with a piece of aluminum and bolted it on with aluminum straps. It was OK, but I never liked it as it was difficult to bend portions of it up and down to adjust the SWR. The integrity of the electrical connection between the conductor and the fin was also doubtful. I thought there had to be a better way.



A 70 cm helix antenna with a ground plane plate 1/4 wave matching section. The center square is aluminum. The support for the N connector is plastic. Using metal in place of the plastic will result in bumps in the SWR with frequency.

During this period I purchased a power divider to feed two 70 cm helical antennas. After looking at them and reading up on quarter wave transmission line impedance transformers, I discovered that power dividers are one of the easiest VHF/UHF devices that an amateur can build. I have since constructed and used two and four way power dividers for 2m, 70, 23 and 13 cm. Then, browsing through the literature on transmission lines and stripline circuits, I realized that you could make a quarter wave match with a section of circular wire over a ground plane. Instead of adding a fin to the conductor why not put a fin or ground plane under the conductor.

For a quarter wave section to match a 140 ohm antenna load to a 50 ohm line it must have an impedance (Z) of 84 ohms where $Z = \text{the square root of } 140 \times 50$. A circular conductor above a ground plane has an impedance defined by $Z = 138 \log 4h/d$, where h is the height of conductor above the ground plane and d is the diameter of the conductor. The diameter of the aluminum wire is .125 inch so the spacing works out to .127 inch, or in this case, for practical purposes, equal to the diameter of the wire.



A 23 cm helix antenna with ground plane plate feed matching. Using an adjusting screw here would facilitate adjusting for minimum VSWR.

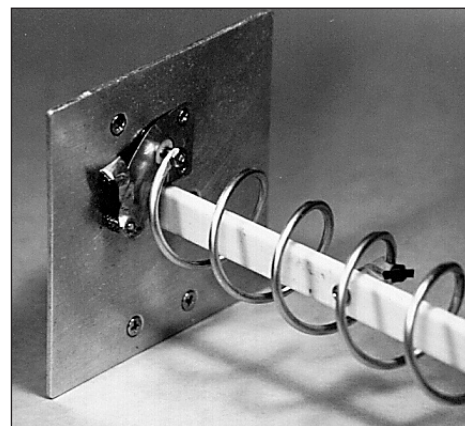
A quarter wave matching section can therefore be made by placing a curved ground plane plate under the last quarter turn of the helix. The ground plane should have a width of ten times or more of the diameter of the helix conductor. The length should be equal to one quarter wavelength of the design frequency of the helix antenna. It can be constructed from aluminum or hobby brass and is cut to follow the curvature of the helix.

I then constructed a 10 turn, 70 cm helix antenna and tried out my idea. I had also found a much better material than pine for

booms. I chanced upon fiberglass stiffening stakes that are used for wire fencing and sold by building supply stores. It is also very light weight, strong and durable. I also had purchased an AEA graphic antenna analyst which, although quite expensive, has more than paid for itself over the years. On first try the SWR was very high and no amount of adjusting the spacing would bring it down. But while trying various adjustments, I noticed that when my screwdriver touched both the fin plate and the helix reflector underneath the SWR dropped.

I discovered that for the ground plane plate to operate properly as a ground plane both ends of it must be grounded. One end is grounded at the feed coax connector with the screws bolting the connector to the reflector. The raised end is grounded directly to the reflector underneath with a short piece of coax shielding braid or a piece of shim brass folded in a U shape. To get the conductor to ground plane fin spacing close to the required .127 inch dimension at the N connector with the 4/40 brass screw soldered into the center pin, I set the type N female chassis connector back from the reflector by using additional nuts for spacers. With this construction I easily obtained a flat 1:1 match over the entire 70 cm band as indicated on the AEA sweep SWR analyzer.

As an added feature, an adjusting screw may be used to adjust the space between the matching ground plane plate and the helix conductor. Do not rely on the screw for the open end ground. Either insulate the adjusting screw or insert the screw through



A 13 cm helix antenna with a 1/4 wave ground plane plate matching section. This one has an adjusting screw, which really is not necessary for receive only.

a stainless steel or phosphor bronze coil spring so as not to have an intermittent connection.

I have used this method very successfully on 70 cm, 23 cm and 13 cm helix antennas. The SWR on my 23 cm helix antennas designed for satellite work at 1269 MHz is still very low at 1296 MHz for terrestrial operation. For 13 cm receive only amateur satellite use, an approximate match obtained by just measuring the spacing will give as good a signal on your S meter as a measured 1:1 obtained on an analyzer. For transmitting on 70 cm and 23 cm where you want to get all you can of that 10 or 25 watts into the antenna, getting a 1:1 match can make a significant difference.

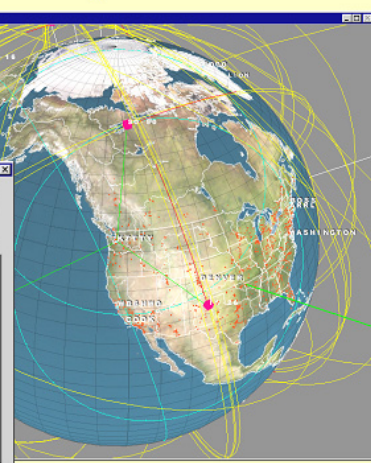
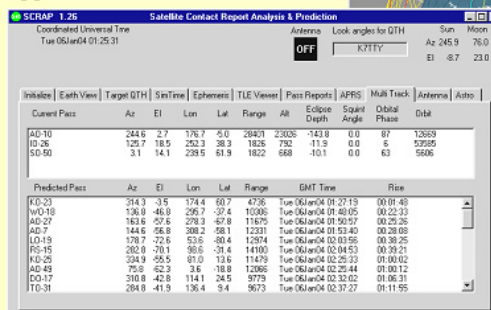
When making SWR measurements and adjustments you should connect your SWR meter through a barrel connector right at the antenna. If you must use a piece of coax it should be a multiple of an electrical half wave in length. If you do not add the adjusting screw use a plastic rod to bend the ground plane plate to adjust the spacing between it and the conductor and you should be able to go through a minimum where the SWR is close to 1:1.

The pictures give examples of the method of construction of the quarter wave ground plate matching section for 70cm, 23cm and 13cm helix antennas. While not part of the matching method, some of my helix antenna construction methods are also indicated. And to those sharp eyed hams I readily admit that I am not a particularly good craftsman. But I will argue that what I make is durable and works well in practice as attested to by the several thousand satellite QSO's in my log book all made using home brew antennas.

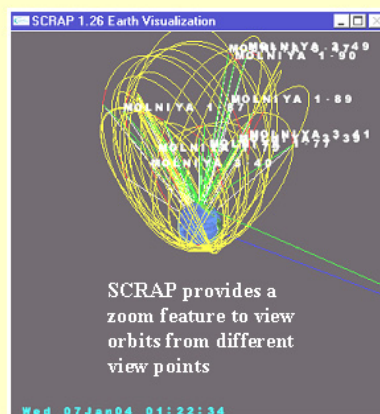
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Journal

Satellite Contact Report Analysis Prediction

AMSAT is now the North American distributor of SCRAP, a tracking program designed for ham satellite applications for Windows 95+



SCRAP provides a real-time contact report and display for over 2000 satellites on a Microsoft Windows 95+ Pentium platform.

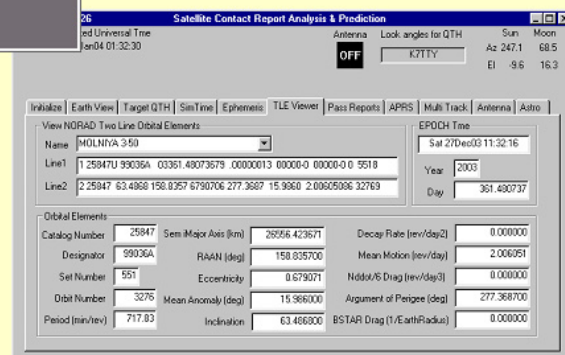


Performance Features

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 - b. Lakes, rivers, islands
 - c. National boundaries
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6. Multiple ground station support
7. Antenna rotor Az/El control
8. Internet updates
 - a. Two line orbital elements
 - b. APRS station locations
9. Astronomical data
10. Simulation

Eleven panels provide for controlling functionality

1. Initialization
2. Earth View
3. Target QTH
4. Simulation
5. Ephemeris
6. TLE Viewer
7. Pass Reports
8. APRS display
9. Multi-Track display
10. Antenna rotor control
11. Astronomical prediction



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The author, Bill Bytheway, K7TTY donated SCRAP to AMSAT. All proceeds support AMSAT.

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Control Software for the Bochum Radio Telescope

by James Miller, G3RUH, g3ruh@amsat.org

Introduction

The 20m radio telescope at Bochum, N. Germany was inaugurated in 1965. Under the observatory's director, the late Prof. Heinz Kaminski, the instrument captured the German public's imagination for a couple of decades, representing the face of space matters in general, and the Apollo program in particular, through the '60s and '70s. In later years the antenna tracked Earth resources satellites for research purposes. Sadly, with the retirement of its champion, declining resources and changing interests the telescope fell into disuse and finally neglect in the '90s.



The parabola is 20m in diameter, and has an $f/d = 0.35$. The sub-reflector is 3m in diameter and the overall focus is at the center (vertex) of the parabola. Access to the focus room is via a circular staircase inside the azimuth column.

In 1999 the radome blew down in a storm. A concerned public rallied around immediately; the state of Nordrhein-Westfalen was

approached, agreed to adopt the telescope as an Industrial Monument and provided sufficient funding for its restoration to a safe condition. The dome was replaced, as well as the pressurization, space heating and diesel-electric back-up power generation. Public outreach activities were to be provided in return by the curators.

The antenna control arrangements however were long obsolete and beyond practical use. Punched paper-tape based; several racks of electronic modules which, predating integrated circuits, had one logic gate/card; enormous DC motors powered by AC-DC motor-generator sets; enough power switchgear for a small town; that stuff was never going to be revived.

This state of affairs coincided with AMSAT-DL needing a substantial ground station for the Phase 5A mission to Mars. AMSAT-DL agreed to get the telescope control systems up and running in return for priority use of the dish. Many, many people pitched in to make this happen.

Thus it was that in 2003 the author was invited to write the software to control the telescope. Every ham secretly wants to play with a really big antenna ... I got my chance!

The Telescope

The telescope has two similar drive trains; one for elevation and one for azimuth. Each axis has two motors; one on each end of the elevation shaft, and one each side of the azimuth ring gear, which is about 2m in diameter. The two-motor concept eliminates backlash.

The computer's job is to calculate a desired azimuth/elevation, measure the present azimuth/elevation, determine a suitable current for each motor (which will create

the torque) and deliver this current request to the four motor drive amplifiers.

The telescope beamwidth at 10.4 GHz is 0.1° . Thus the objective was set to be able to track with pointing accuracy better than 0.01° . This is achieved at about an order of magnitude better.

The telescope, as seen by the computer, consists of four 19200 baud RS-232 serial lines and a handful of status bits. A pre-existing brand new unused, though 6-year-old 233 MHz StrongARM (DEC/Intel SA-110) RiscPC [10], was augmented with two dual serial port cards and a 16 bit parallel I/O expansion card, and the computer hardware was complete. Precise time information comes from a Jupiter-T GPS timing receiver attached to the standard serial port. [3]

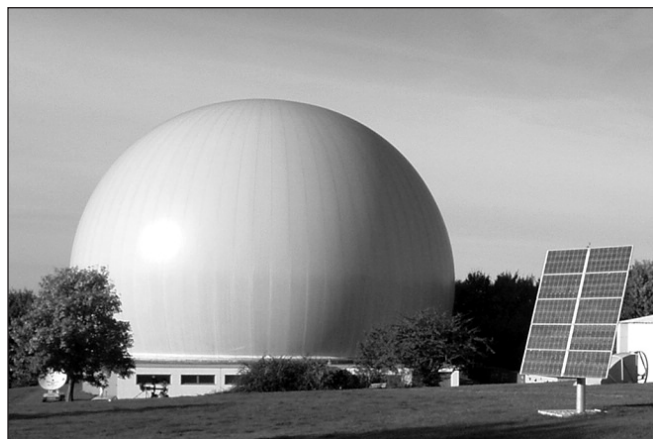
The control computer, called *Bocc* is also connected by Ethernet to a site management computer called *Bomex* which is permanently connected to the external Internet. So *Bocc* telescope control software can be updated remotely, and indeed the telescope also can be operated remotely, with just a couple of clicks, from home.

Bomex (the site management computer) runs Unix (FreeBSD 4.10) and services two cameras, the control computer as above and eventually radio receivers, test equipment and other functions TBD. This machine is maintained by Rainer Rutz, DF7DD.

Commissioning, Round I

I loaded the new control computer, plus my own everyday computer system, on which the software was developed, a considerable library of books/manuals, a couple of boxes of tools and test equipment etc into the car, and in October 2003 drove to Bochum for an initial fitting. The control computer was wired up to the telescope, networked to my nearby development RiscPC and initial checkout began.

Serial port systems never work as advertised, and we had the expected number of gotchas, but at the end of a typically frustrating day one, all the hardware parts were interfacing correctly. Day 2 was then spent getting to grips with the arcane protocols of the motor drive electronics and machinery attached to the serial ports. Fortunately the resident electronic engineer (Hartmut Päsler, DL1YDD) had already jumped through these hoops during prior commissioning



A general view of the (pressurized, ~0.6 bar) dome at Bochum. It's about 40m in diameter. The solar panels are a technology demonstration and pump a few kilowatts into the electricity grid.



A 140 ton roof over your head ... The column is 2m in diameter and rotates on a substantial bearing about 1m in diameter. The LH rack holds four servo motor drive amplifiers. The RH rack has the RiscPC (RPC), UPS, GPS and some odds and ends. My personal RPC is on the left being used as a server holding master copies of the software, which was under development at the time. The telescope RPC ran its software fetched across the Ethernet. Finally it was permanently loaded onto the telescope computer for normal use.

tests, so borrowing from his Turbo Pascal routines was painless and quick.

Midnight Oil

Back in my hotel that night I then devised a simple guidance program using all the knowledge gained thus far, and on the morning of day 3 it was coded. Just a test program to advance the telescope by 20 angular degrees and back again. Remember we are talking about the controlled acceleration, track and deceleration of 140 tons of irreplaceable historic machinery. This was not a task undertaken lightly, however simple it seems on paper. With great trepidation I tapped the keyboard. The instrument groaned into life, and did precisely what it was asked. After 15 years enforced uselessness, and 5 years of restoration it had at last come truly alive!

Many more tests followed. By the end of the day we had a basic working control system which would move the machine with a repeatable accuracy of about 10 arc-seconds. That's the angle subtended by the thickness of a matchstick at 50 meters and about an order of magnitude finer than our goal.

Advanced Software Development

Back home I spent the next month turning the primitive material into a much more functional engineering tool. This offers various step functions, slew rates and so on, plus the ability to track Sun, Moon, planets, certain radio emission stars, interplanetary probes and earth-orbiting spacecraft. All this was completely dynamically tested at home, without using the real telescope, via

the built-in simulation.

The software is written in BBCBASIC, and runs stand alone. This is a machine control system and the computer is not required to do anything else other than its dedicated task. It cycles around a loop 20x per second calculating the desired azimuth and elevation angles, reading the position sensors and computing the required motor drive currents to keep the telescope on track. Next an almanac of the positions all the objects it knows about is updated, one object per loop. The almanac is visible to the operator who can choose the target from it. Finally, servicing the GPS receiver, scanning the keyboard, and displaying engineering data on the screen take but an instant. Doing all this, the computer is about 50% loaded. There is no hardware floating point (f.p.) unit.

Commissioning, Round II

In November 2003 the telescope was revisited with the engineering-grade software essentially fully developed, without it having been near the real thing. After aligning the telescope's azimuth axis to the calibrated datum plate on a wall, the instrument was told to track the Moon. I pressed the button. The machine rumbled into life, and slewed towards the Moon. The radio engineer (Freddy de Guchteneire, ON6UG) watched his noise power meter; bang on cue, up came the radio noise level as the Moon swung into the beam.

Some fine calibration of the position sensors was performed, and the telescope was set to point at the very noisy radio star Cassiopeia A. After a few moments the radio noise level increased slightly as the famous super-nova- remnant, which exploded in 1667, came into the beam.

A final test was to track the ESA spacecraft Mars Express then en route to the planet, and 'only' 100 million km distant. The command was given, the telescope slewed to the spot just East of Mars, and when it had settled the receiver was slowly tuned (8.4 GHz) to locate the space probe's telemetry beacon. From the radio came a squeal as the probe's telemetry beacon was tuned in. It had the correct frequency, correct Doppler

shift profile, and disappeared when the telescope was off-pointed slightly. It was indeed Mars Express. We were in business.

Since then (2003-2005) all the NASA/ESA spacecraft have been regularly tracked, and provide perfect space borne beacons for azimuth and elevation calibration, sanity checks, as well as excellent demonstration tools in fulfillment of the observatory's 'outreach' mandate. A feed is also fitted for 1.6 GHz weather satellite reception, with the results available for visitors to watch.

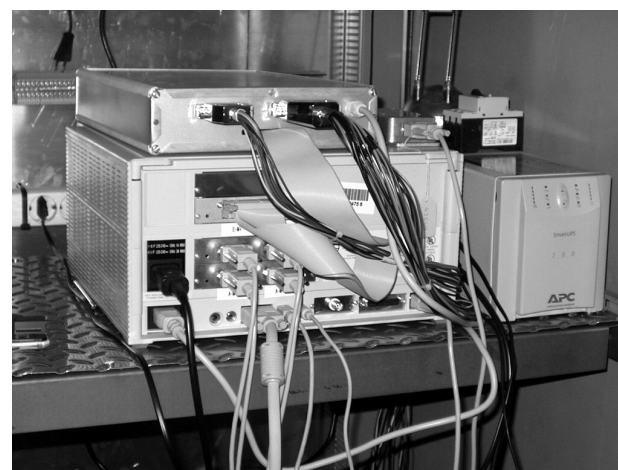
Evolution of System Software

The development of this kind of system follows a reasonably standard path, although it's not necessarily a straight line as interdependencies have to be explored. There are several identifiable elements; plant simulation, servo-controller, and the demand manager. Software implements these and makes the telescope machinery perform as desired.

Plant Simulation

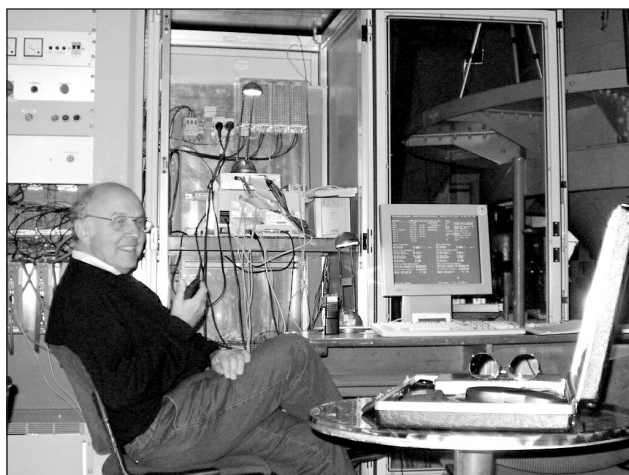
The real telescope consists of motors, gearboxes, chunks of inertia, friction, torsion elements, sensors and so on. The first job was to create a simulation of these elements. With this tool a good idea of the telescope dynamics can be gathered. This is important because it influences the design of the control system.

By applying impulse, step and sinusoidal excitations to the plant simulation, most things of concern can be modeled and discussed. Quite a lot of time was spent exercising this, well before the main



Danger! Non-PC PC at work! Two dual Serial Port cards interface to four servo amplifiers in the LH rack. Top slot has a 32-bit parallel I/O card with ribbon cable to a box above full of opto-isolators and relays. Small box on top is GPS receiver for precise UTC via standard serial port. BNC socket is Ethernet connector. To the right is a UPS (uninterruptible power supply). The electronics in view here essentially replace as much old stuff as would fill a small apartment.





Karl uses a radio. Two of the four Eurotherm motor drive amplifiers can be seen behind Karl Meinzer, DJ4ZC. HT's are used for communicating from control room to focus to control racks and generally around the site.

telescope package was written. Often a simulation is discarded after use, but in fact this one is very usefully retained, as will be explained.

Servo-Controller

The principal objective is position following, so proportional control is required. But the telescope is always moving, and a proportional system will lag behind unless rate control is also incorporated. Factors such as friction and stiction and small non-linearities can also disturb the tracking accuracy. These are mopped up by an integrator, so the overall system is described as PID (proportional, integral, derivative) control.

There is a servo controller routine for each axis. They are similar, differing by constants due to the differing inertias and gear ratios of the machinery. The controller takes the demanded azimuth and elevation, compares them with the measured azimuth and elevation (which is available from the motor drive amplifier units) and computes the required motor current to move the telescope in the optimum way.

Presently the calculations are done at 50 ms intervals (20x per second); this rate is considerably faster than the natural frequencies of the machinery and is set by the speed of calculation of demands.

Testing of the servo-controller was done initially using the previously described Plant Simulation as a substitute for real machinery. In the final software this feature is retained by the setting of a flag the software can control the real telescope or the simulated telescope;

numerically it cannot tell the difference. This allows software development to be continued away from the real instrument.

Demand Manager

The "demand" is what you want the telescope to do. Usually this is to track an astronomical object, but it can also be, say, "move +10 degrees". The demand manager looks after these matters according to the wishes of the user and creates azimuth

and elevation demands to track:

- Sun, Moon and Planets
- Interplanetary probes
- Stars
- Earth orbiting satellites
- Goto fixed points
- Step changes in position (for test purposes)
- Fixed rate of movement (pan)
- Stop!

In the early stages of development, only the last three items were of interest. Using these, the tracking performance could be gauged. Later, the astronomic tracking was introduced.

Astro Package Revision

The original astronomical package was written using routines that used harmonic series to calculate the bodies' coordinates (abridged VSOP87 model). This is how it has been done traditionally and the method has advantages and disadvantages.

However, we also had a requirement to compute range-rate of bodies and I decided at this point to 6-space vectorialize everything and change the astronomic package over to use the JPL Planetary and Lunar Ephemeris DE405/LE405 [8]. In this the solar system bodies' 3-dimensional coordinates are represented by coefficients over a basis set of Chebyshev polynomials. The original JPL Solar System numerical integration, which has formed the basis of professional solar system positional astronomy for many years and of the Astronomical Almanac since 1984, can be recreated to meter-level accuracy with remarkably little calculation.

This required a rationalization of everything to do with astro-tracking, and the package is even more accurate and certainly more flexible than it was. It is able to calculate objects' coordinates properly, accounting

for the whole litany of small corrections without regarding each as a special case and with various degrees of approximation. These are:

- Light-time correction (excepting stars)
- Gravitational deflection of light by the Sun
- Aberration; due to velocity of Earth around Sun
- Diurnal Aberration; due to velocity of observer on the Earth
- Parallax due to observer's position not at Earth's center
- Annual parallax; due to Earth's position change around Sun
- Precession; Earth's spin axis 25,000 year circular motion in space
- Nutation; wobbly motion in space
- Polar motion; Earth's pole not fixed to ground

That is, "everything". All computations are vectorial and for the most part in 6-space (3x position + 3x velocity). The detail is documented in [1,2].

After conversion to the observer's horizontal plane, Elevation (including refraction), Azimuth, Range and Range-Rate are output to the user.

This re-organization took place in 2004 January, and worked perfectly (without even a visit to the telescope).

Accuracy

The program is executed using BBCBASIC in 5-byte f.p. mode, which provides 9.6 decimal digits of resolution. This means that calculations of azimuth and elevation emerge at around 0.000001° fundamental accuracy, or about $0.005''$.

The astronomic algorithms are essentially exact at the $0.05''$ level. The greatest source of error is incorrect refraction correction (elevation) and timing uncertainties (azimuth). These errors are unlikely to exceed $5''$.

The following table gives an indication of typical error source, magnitude and type:

For comparison:

Item	Source	Typical Magnitude	Error Type
1	5-byte floating point	$0.005''$	rms
2	Ephemeris calculation	$0.05''$	rms
3	Antenna location	$0.05''$	bias
4	Computer clock	$0.2''$	az bias, max
5	Refraction	$5''$	el bias, max

Motor control system is mechanically repeatable in azimuth at the $\sim 10''$ level.

Sternwarte Bochum Radio Telescope Control					Version 3.6 by KM, HP, JRM	
2005 Jun 29 [Wed] 1213:50 utc					Weather	25C 1020 mb
Almanac Object	Azimuth deg	Elev deg	Range M km	Doppler Hz/MHz	Keys	
1 Sun	198.67	60.79	152.082696	-0.327	0 - 9	Track astro object
2 Moon	276.01	2.85	0.380442	-1.089	P/p	Change Planet
3 Venus	151.79	57.51	227.622769	27.473 <<	X/x	Change probe s/c
4 Rosetta	79.17	-38.30	67.276182	-45.237	S/s	Change Star
5 Cas A	327.46	31.39			Z/z	Change satellite
6 AO-40	114.66	5.06	0.063956	1.270	TAB	Alternative P X S Z
7 Mercury	151.49	57.07	148.871004	97.267	Home	Go to Datum Plate
8 Cassini	158.98	58.09	1500.138454	-25.082	F/f	Change Fixed object
9 Cyg A	351.23	2.96			H	Go to Horizon (EL=0)
0 ASTRA 1C	164.90	30.14	0.038596	-0.007	A/E	Step or Rate to AZ/EL
RA 8h 16m 37.65s Dec 21° 19' 02.4"					<>	Step +/- 10°
					R/r	Rate select +/-
					SPACE	Hold position (Stop)
					↕ ↖ ↗ ↘	Adjust offset 0.01°
					SHIFT+↕ ↖ ↗ ↘	 1.00°
					RETURN	Zero offsets
					T/t, L/l	Set temp, pressure +/-
					Q	Quit
Data from User					Data from User	
AZ_demand	151.8095 °				EL_demand	57.5133 °
AZ_offset	0.00 °				EL_offset	-0.04 °
Data from controller					Data from controller	
AZ_Phi_Soll	151.8095 °				EL_Phi_Soll	57.5158 °
AZ_Phi_Soll_Fi	151.7958 °				EL_Phi_Soll_Fi	57.5140 °
AZ_Phi_Ist	151.7957 °				EL_Phi_Ist	57.5140 °
AZ_Delta_Phi	0.0001 °				EL_Delta_Phi	0.0000 °
AZ_Integral	0.003				EL_Integral	0.004
AZ_M_plus	0.206				EL_M_plus	0.208
AZ_M_minus	-0.100				EL_M_minus	-0.100
Data to/from Eurotherm					Data to/from Eurotherm	
Position counter M+	0xF620825B				Position counter M+	0xFB24B7CE
Position counter M-	0xF620825B				Position counter M-	0x04DB4832
Motor current M+	14 /70				Motor current M+	-14 /70
Motor current M-	-7 /70				Motor current M-	-7 /70
Run time 0:0110:19					Time used: 3 cs of 5 cs	

Software screenshot. This is engineering checkout software so it single tasks and the user interface is straightforward. Later may come multitasking although for an embedded system there seems little point. Lower half of the screen is diagnostic data from the servo-controller algorithms.

Diameter of Mars at closest approach is ~18"

At X-band (10.4 GHz), the Bochum antenna 0.25 db beamwidth is 100"

1. 5-byte floating point: Comparisons with 8-byte floating point arithmetic indicates that provided care is taken with the representation of time, angles are calculated to about 0.000001°. This is negligible uncertainty.
2. Ephemeris calculation: The JPL ephemerides are extremely accurate. The subsequent reduction has some very small simplifications in respect of timescales and axes which introduce the indicated uncertainty. These are orders of magnitude less than more practical matters, and are insignificant. Ephemeris of Earth satellites (via NORAD 2-line elements) are much less accurate than for astronomical bodies, but remain

substantially within beamwidth at the 1-2 GHz region typically used.

3. Antenna location: This has been determined using GPS and is presently well within 1m and improving over time. However dish focus location changes with azimuth and elevation by 1-2m, and this leads to location errors of order 0.05". This error is systematic, and could easily be removed algorithmically.
 4. Computer clock: The Bochum telescope software takes UTC from a GPS receiver at regular intervals. The maximum service latency is typically 10 ms, equivalent to an error of typically 0.2", mainly to azimuth. The latency could be reduced to zero by using an interrupt rather than a polling process.
- UT1 (for Earth rotation calculation) is taken from IERS Bulletin-A [9] and

may be considered exact at our level of interest.

5. Refraction: This is corrected using a model designed for optical observations. The optical formula is accurate to about 5" when more than a few degrees above the horizon, provided temperature and pressure are set correctly. At radio wavelengths humidity enters as a factor and adds between 0 and 10% to the refraction correction over the range 0 to 100% RH, but this is ignored.

Summary: for practical purposes, azimuth and elevation calculations are unlikely to exceed 0.001° at low elevations (below 5°), 0.0001° at high elevations and may be considered 'exact' compared with the required accuracy of 0.01°.

The astronomical routines are kept in a software library and so are in constant use



by support utilities such as forward planning, backward analysis, mission studies, almanac generation and Doppler calculation to 1 Hz at X-band. The apparently surplus precision is no disadvantage.

Conclusion

In this article I have outlined the processes through which a radio telescope control system was implemented, from the initial ideas to a reliable working tool in constant use by AMSAT and by the Sternwarte Bochum personnel. In a future article I will describe the astronomic algorithms in more detail. Comments and money may be sent to callsign@amsat.org.

Acknowledgments

Valuable assistance in the development of this program was given by the following people, for which my thanks:

Dr Peter Duffett-Smith of the Mullard Radio Astronomy Observatory (MRAO) in the University of Cambridge for positional astronomy advice, and sharing algorithms for pre-JPL ephemeris versions (up to v2.3) of the software.

Dr. Karl Meinzer, DJ4ZC, (University of Marburg) specified the servo controller and

the simulator model used in this program, and tuned them to match the telescope dynamics. He is instrumental in pushing along the AMSAT program.

Hartmut Päsler, DL1YDD, reverse engineered the Eurotherm motor controller interfaces and contributed the know-how to make the serial protocols work straight off. He was/is responsible for the electrical refurbishment of the antenna motor systems.

AMSAT-DL has been the driving force behind the modernization of the telescope tracking and control system; hardware, software and management.

References

The following books are essential companions to this work:

1. Seidelmann, P.K. (ed), "Explanatory Supplement to the Astronomical Almanac", 1992, University Science books, ISBN 0-935702-68-7 <http://www.uscibooks.com/>
2. The Astronomical Almanac 2004. Published annually by USGPO and TSO.
3. The GPS timing receiver is described at: <http://www.jrmiller.demon.co.uk/projects/ministd/frqstd.htm>

Further useful references are:

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9. IERS Bulletin A contains dAT and dUT offsets, as well as polar motion: <http://maia.usno.navy.mil/ser7/ser7.dat>
10. The RiscPC is no longer produced, but its prized successors are described at <http://www.iyonix.com>



STRAIGHT KEY NIGHT ON OSCAR 2006

Once again AMSAT NA is pleased to sponsor Straight Key Night on OSCAR for enjoyment by all radio amateurs. OSCAR SKN 2006 will run for 24 hours, 0000-2400 UTC, on 1 January 2006. It's very simple: no rules, no scoring, and no need to send in a log. Just operate CW through any OSCAR satellite using a straight hand key, working as many other SKN participants as you can. Contacts via the moon (OSCAR Zero) count too.

As in past years, all participants are requested to nominate one of the operators they worked for "Best Fist" recognition. Your nominee need not have the best fist of those you heard, just of those you worked. Please send all nominations to me at w2rs@arrl.net (Note the new address. My old address, w2rs@amsat.org, only works sporadically now due to ISP problems at this end.) A list of those nominated will be published via the AMSAT News Service in early February, and in *The AMSAT Journal*.

73,
Ray, W2RS
for AMSAT NA



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This is SUITSAT-1, Amateur Radio Station RS0RS!!

by Frank H. Bauer; KA3HDO, ka3hdo@amsat.org

Amateur Radio on the International Space Station (ARISS) International Chairman

AMSAT Vice President for Human Spaceflight Programs

NASA Goddard Space Flight Center

Introduction

"This is SUITSAT-1, Amateur Radio Station RS0RS!!"

These words will echo from space in the near future, inspiring students, exciting ham radio operators and touching the world. If all goes as planned, a unique Extra-Vehicular Activity (EVA) - or spacewalk will be conducted on the International Space Station (ISS) in early February 2006. During this spacewalk, the ISS crew will push a Russian spacesuit overboard - with no humans in it, of course! But this Spacesuit holds the hopes, dreams and creativity of students around the world. And for a week or two, this Suit-robot-satellite will take on a life of its own - parroting students' voices from around the world, voicing down suit health telemetry and sending a special commemorative picture to all who want to receive it.

Suitsat-1 (also called Radioskaf or Radio Sputnik in Russian) mission activities will be conducted on the Amateur Radio (ham radio) frequencies, a bit above the FM broadcast band. The voice signals can be picked up with ham radio receivers and FM VHF (Very High Frequency) scanners - like police-band scanners.

Students, scouts, teachers, ham radio operators and the general public are encouraged to track the space suit, hear the conversations from space, copy the suit telemetry and capture the picture. A special certificate will be distributed to those who receive the voice signals and those who capture the picture. We also will have a special award for those students who receive the "special words" that are embedded in the messages from our SuitSat student "crew members." These special words are in different languages - English, French, German, Spanish, Russian and Japanese. So you are encouraged to record the SuitSat downlink audio and get help from fellow students who know these languages.

Also included in this spacesuit is a computer Compact Disk (CD) with images of over 300 items collected from schools and educational organizations around the world. These include creative works of art from students as well as student signatures, school or scout logos and class or group pictures. Students,

schools and educational organizations that participated in the development of this disk earlier this year will all be part of the SuitSat spacewalk - as their creative works, signatures and pictures all float in space!

The following will provide more details on the Suitsat-1 mission and provide you information on how you and your school can participate.

The Suit and On-Board Equipment

Through the miracle of ham radio, the ingenuity of the international space agencies, the help of students and schools and the tireless work of a few volunteer "rocket scientists" Suitsat-1 was born.

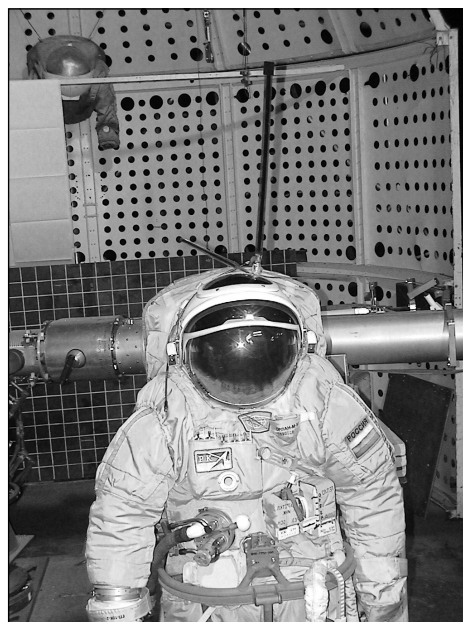


Figure 1: Russian Orlon Spacesuit.

SuitSat is sponsored by ARISS (Amateur Radio on the International Space Station), an international working group consisting of volunteers from national Amateur Radio societies (the American Radio Relay League in the U.S.) and the internationally-based Radio Amateur Satellite Corporation (AMSAT).

The idea for SuitSat was first conceived by the ARISS - Russia team, led by Sergey Samburov, RV3DR, and was extensively discussed at the joint AMSAT Symposium/ARISS International Partner meeting in October 2004. The project is being led by project manager A. P. Alexandrov and

Deputy Project Manager A. Poleshuk from RSC Energia, located in Korolev (Moscow area) Russia. The project was developed primarily by a joint US/Russian team. On the US side, the hardware project development was led by AMSAT member Lou McFadin, W5DID.

Embedded in the Russian Orlon Space Suit (Figure 1) are two boxes housing the ham radio transmitter and the micro-controller and electronics that stores and plays back the digital voice and video recordings. Also inside the spacesuit will be some batteries to power the system and the "School Spacewalk" CD. On the outside of the spacesuit are the SuitSat antenna and the crew interface control box - the crew interface device that turns the SuitSat power on. See Figures 2 to 3. Prior to the spacewalk, the ISS crew connects cables to the two internal boxes (the Kenwood transmitter box and the micro-controller electronics box), Figure 4, and stores these two boxes in a fabric container that is housed inside the space suit (see Figure 6). Next, they mount the antenna and the interface control box to the exterior of the suit helmet as shown in Figure 2. Next, the batteries, interface control box and antennas are all connected to the two internal boxes with special connecting cables. The SuitSat is then ready for deployment. Once the crew is outside on their EVA, they turn all three switches on the control box to the ON position and deploy the spacesuit from ISS. Their objective is to put Suitsat in a retrograde orbit so it "de-orbits" relative to ISS. This orbit will appear from the ground to be ahead of the ISS, while it is actually slowing down and is below ISS.

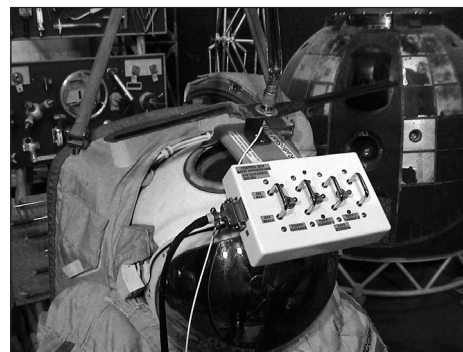


Figure 2: SuitSat Antenna and Crew Interface Control Box.

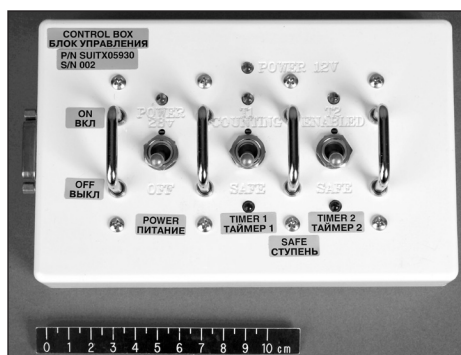


Figure 3: Crew Interface Control Box.

About eight minutes after the crew flips the three switches, the Kenwood transmitter, Figure 5, will power up. About eight minutes after that, the first voice telemetry message will be transmitted and SuitSat operations begin! (This 16 minute delay is a crew safety measure).

Please remember that this mission is battery operated. In other words, when the batteries

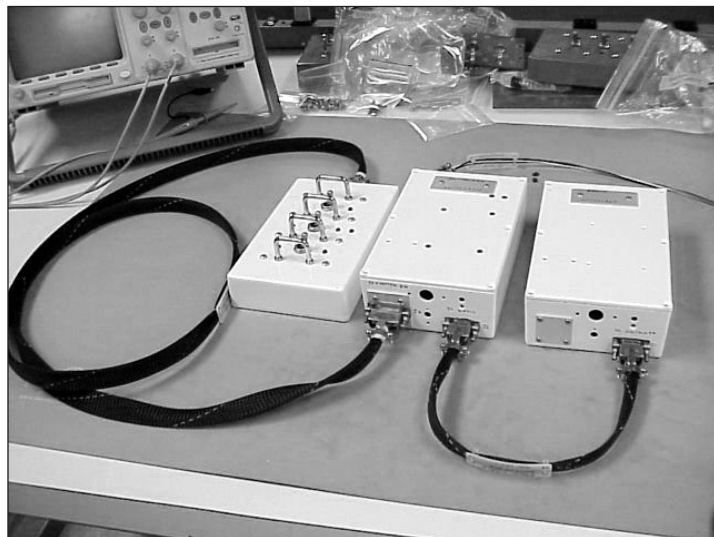


Figure 4: SuitSat Interface Control Box, Transmitter Box and Digitalker/Micro Controller Box.

run down, SuitSat stops transmission. We also do not know how fast SuitSat will heat up. So our ability to predict mission life is not very good. Our prediction is 1-2 weeks. However, it may stay on for as little as an hour or as long as several weeks. So if you want to hear SuitSat, your objective is to get prepared for SuitSat operations ahead of time.

Suitsat-1 Transmission Specifics

All transmissions will be on 145.990 MHz FM. This is in the VHF (2 meter) portion of the Amateur Radio band. It can easily be picked up with a simple VHF hand-talkie ham radio, although ground-based antennas with higher gain are preferred to hear SuitSat for the entire 10 minute pass. SuitSat audio

can also be received using a police band scanner. An external antenna is highly encouraged. SuitSat will be transmitting 0.5 watts into the same type of antenna currently used on the ISS ham radio station.

Additional Downlink Frequency and Information for Ham Radio Operators

Since SuitSat will be operating on the ISS world wide packet uplink frequency of 145.99 MHz, it is requested that all packet operations on that frequency be suspended for the duration of the SuitSat transmissions. Keeping transmissions off the downlink frequency will help to avoid local interference to the 1/2 watt downlink signal from SuitSat.

The ISS crossband repeater is under consideration for being temporarily reconfigured to listen for the SuitSat transmissions and then retransmit them on 437.80 MHz. It is hoped that persons with minimal equipment might have a better chance of hearing the SuitSat retransmissions from the crossband repeater since ISS has a power output of 10 watts. Please help us to avoid interference problems by not using the crossband repeater while SuitSat is active because anything else the repeater hears on 145.99 MHz will interfere with the

SuitSat retransmissions.

Tracking Suitsat-1

If you plan to hear Suitsat, you need to know when it will be visible in your area. To do this, you need to obtain some orbit prediction software or see the ISS orbital path from the Internet. Information on this can be found at the following:

<http://www.amsat.org>

<http://www.amsat.org/amsat-new/tools/>

<http://science.nasa.gov/Realtime/jtrack/>

Please understand that when you use an orbital prediction program you need an accurate synchronization of time (to a few seconds).

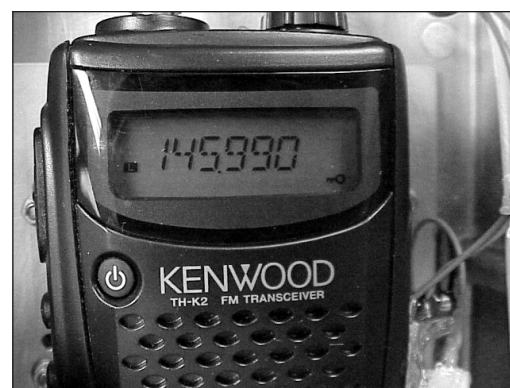


Figure 5: Kenwood TH-K2 Transmitter

Downlink Specifics

To fully understand the Suitsat-1 downlinks, some background information is in order. One of the reasons our Russian colleagues were interested in developing SuitSat was as an on-orbit commemoration of the 175th anniversary of the Bauman Moscow State Technical University. This university is where many of the engineers in the Russian Space Agency graduated. As a result, the Russian-generated messages include congratulatory comments to the Bauman Moscow State Technical University.

In addition to the messages from Russia, there are voice messages from students in Japan, Europe (Spanish and German), Canada (French) and the USA (English). The USA message is from a student enrolled in the Eastern Middle School, Silver Spring, Maryland. Eastern Middle School is a NASA Explorer School. In addition, the Suitsat-1 ID was voiced by a Korean-born young lady enrolled in Paint Branch High School, Burtonsville, Maryland, USA. As you can see, Suitsat-1 truly has an international flavor!

Special Word

Several of the student messages include a special word. One student project for SuitSat will be to copy all the special words (in different languages) and submit them to the ARISS team for special educational award recognition.

Suit Telemetry

The suit telemetry is sensed by the SuitSat microcontroller and converted to a voice message. Three telemetry data messages will be transmitted. These will be periodically repeated. Specifically, the suit telemetry will be transmitted in the following order:

- Mission Time
- Suit Temperature
- Battery Voltage, where 28 Volts is the nominal voltage

The SuitSat team is quite interested all three pieces of telemetry as it will be a predictor for SuitSat mission life.

SuitSat Downlink Picture

The downlink picture will be transmitted using a set of audio tones, similar to a computer modem, using a ham radio picture standard called Slow-Scan Television (SSTV). SSTV, developed many years ago, provides cell phone quality pictures. A single picture was installed in the SuitSat microprocessor memory and will be downlinked. SuitSat uses an SSTV data transmission standard called Robot 36. This standard sends the entire image in 36 seconds.

For more information on SSTV, you may check out:

<http://www.marexmg.org/spacecam/spacecam.html>

<http://www.ultimatecharger.com/SSTV.html>

Suitsat-1 Downlink Sequence

Now that you understand the specifics, what can you expect when SuitSat is over your area? To save SuitSat power and to maximize the time that SuitSat is operational, 30 second pauses have been included between each of the voice messages. So the sequence will be as follows:

- SuitSat Voice ID (5 seconds)
- International voice message, Suit Voice Telemetry, or SSTV Image (15-45 seconds)
- 30 second pause
- and repeat

The international message order will be as follows:

- Voice Telemetry
- Russian Message
- Europe Student Messages (Spanish and German)
- Bauman Institute Message (Russian)
- Canada Student Message (French)
- Mr. Alexandrov Message (English)
- Japan Student Message (Japanese)
- USA Student Message (English)
- SSTV Picture

Copying SuitSat Data

If you are planning on copying the Suitsat-1 downlink, you are highly encouraged to record it so you can replay it later. Tape recorders or digital voice recorders with at

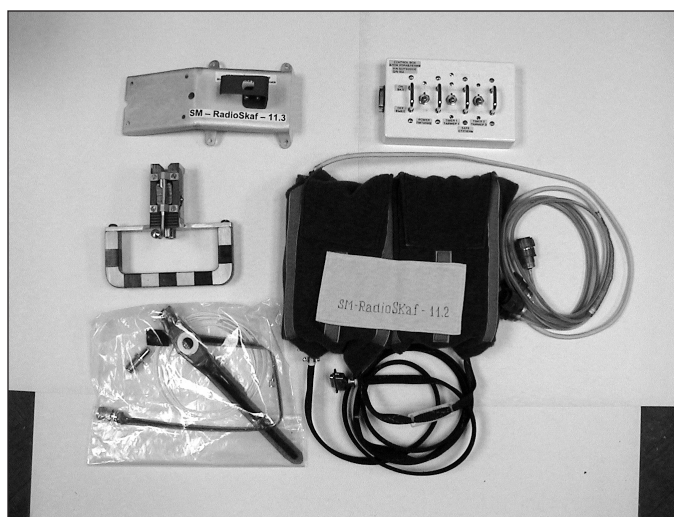


Figure 6: Suitsat Hardware (Transmitter and Digitalker/ Microcontroller Box inside Fabric Container). least 10-15 minutes of continuous recording are recommended. You can then use these to submit Suit telemetry information, the special words and the SSTV image to the ARISS team and the space agencies.

“School Spacewalk” CD

As part of the SuitSat project, a CD with hundreds of school pictures, artwork, poems and student signatures is included. Two identical CDs were flown, one will go in the suit as part of the Suitsat-1 spacewalk. The other is available for the crew to review. There are approximately 300 items on the CD including artwork, school and educational organization logos, student signatures and student and school pictures. A composite of several of the items installed on the CD are shown in figure 7. As you can see, these are from all over the world (Japan/Asia, Europe, Russia, Canada, US, South America and Africa). Several NASA Explorer Schools participated as well as numerous ESA and Russian Space Agency-sponsored schools.

SuitSat postings of telemetry, special messages and the SSTV Image

This is still a work in progress. Please return to the Web site often to get details on this as the SuitSat mission gets closer.

Special Certificates

Those that hear SuitSat will be eligible to receive a special certificate in commemoration of your achievement. Also, if you receive the SSTV image, copy the telemetry and/or copy the special words, special certificate endorsements will be provided. To receive a SuitSat special certificate, please use the standard QSL card address in your area of the world. These are located at: <http://www.rac.ca/ariss/oindex.htm#QSL's>

Indicate the time and date you heard SuitSat and any other information that will acknowledge your reception of the information (telemetry, SSTV picture, etc.) that will confirm that you should receive the proper endorsements on your certificate. Please include a self addressed stamped envelope. And provide a big envelope and protective cardboard if you do not want your certificate folded or damaged during shipment.

Current Status

On May 10, 2005 NASA gave the OK to fly. Four short weeks later, the USA built SuitSat hardware was sent to Russia for final testing, certification and integration with the Russian-built hardware.

On Thursday, September 8 at 13:08 UTC, Progress 19P lifted off from the Baikonur Cosmodrome in Kazakhstan. Included in the 2.5 tons of fuel, food and supplies was the Suitsat Amateur Radio hardware. The successful docking of Progress to ISS on September 10 culminated the successful design, development, certification and delivery of this exciting educational project. The ISS Expedition 11 crew has unpacked the SuitSat equipment, making it available for installation, use and deployment by the Expedition 12 crew. SuitSat deployment is currently scheduled for February 2, 2006.

Conclusions

The SuitSat project was an extremely challenging endeavor for the ARISS hardware team, primarily due to the very short development time. Throughout the development effort, we have involved students. As SuitSat nears deployment, we are looking forward to the continued involvement and participation of students worldwide.

For all the Amateur Radio operators in the world, this is your chance to get your local school involved. Bring a radio, orbit tracking program, SSTV equipment, an audio recorder and your enthusiasm into the school. SuitSat promises to capture the imagination of the students and, if successful, will allow the students to learn more about space, Amateur Radio and satellite orbits. Please volunteer and wish our robotic astronaut in the Russian Orlon suit a good and successful journey in space!! ☺



ARISS Web site: <http://www.rac.ca/ariss>
 AMSAT Web site: <http://www.amsat.org>
http://en.wikipedia.org/wiki/Orlan_space_suits
<http://www.issfancub.com>
<http://space.cweb.nl/article.html?id=407>
 photo of how cosmonauts get into the Orlan suit

On behalf of the ARISS International team, the author would like to acknowledge and congratulate the Suitsat hardware development team for their “Can Do” spirit and ability to deliver the Suitsat hardware on such a very challenging schedule.

Specifically, we would like to thank the following: Alexander Alexandrov, Alexander Poleshuk, Sergey Samburov, RV3DR, Lou McFadin, W5DID, Kenneth Ransom, N5VHO, Frank Bauer, KA3HDO, Mark Steiner, K3MS, Steve Bible, N7HPR, Joe Julicher, N9WXU, Rawin Rojvanit, Farrell Winder, W8ZCF, Jeffery Winder, KB8VCO, Hiroto Watarikawa, JJ1LYU, Stan Wood, WA4NFY, Herb Sullivan, K6QXB, Dave Taylor, W8AAS, Deanna Lutz, K7DID, Claire Fredlund, Carol Jackson, KB3LKI, Kenwood and Microchip Technology Inc.

The collage consists of six distinct images arranged in a grid-like fashion. The top-left image is a black and white photograph of a child standing on a beach, looking out at the ocean. The top-middle image is a black and white photograph of a satellite in space, with the Earth visible in the background. The top-right image is a black and white photograph of a young couple, with the boy kissing the girl on the forehead. The bottom-left image is a black and white drawing of a house with solar panels, with a person standing in front of it. The bottom-middle image is a black and white drawing of two plants growing out of a mound of earth. The bottom-right image is a black and white photograph of a large crowd of people, with a large building in the background.

The author would also like to acknowledge the tremendous support, teamwork and volunteer spirit of the ARISS-International team as well as the technical, financial and administrative support of the ARISS member organizations - the AMSAT organizations

and IARU organizations (ARRL in the USA). Also special recognition is in order to the space agencies: NASA, Energia, ESA, JAXA & CSA. Together we are pioneering the new frontiers of Amateur Radio and educational outreach. 🌐

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C-C Rider Revisited

Tom Clark, W3IWI, Bob McGwier, N4HY, Phil Karn, KA9Q, and Rick Hambly, W2GPS

(Reprinted with minor revisions from the Proceedings of the 2004 AMSAT Satellite Conference in Arlington, VA)

Abstract

At the 2003 AMSAT Annual meeting, W3IWI presented the concept of a C-band in-band transponder¹, dubbed "C-C Rider". This was based on the fact that the C-band satellite frequency allocation has a matched pair of 20 MHz wide allocations: 5650-5670 MHz uplink, paired with a 5830-5850 MHz downlink.

The status of the 5650-5670 MHz uplink band has changed since last year; the FCC has adopted an industry proposal for expanded 802.11a spectrum, and a world-wide allocation was made at WARC 2003. In this paper we speculate on the QRM level that might exist 5-10 years from now as seen by a C-band receiver on a HEO satellite. We will also discuss the RFI environment to be expected by a typical user at the C-band downlink frequency.

Many of the options that were presented in the previous paper have been considered in the context of a significant part of AMSAT's HEO (High Earth Orbit) Eagle Project. Recent advances in SDR (Software Defined Radio) technology have led to the concept of a modular transponder that can be easily re-configured in orbit.

Since there is little suitable C-band hardware available for the amateur community, we will discuss the idea that the spacecraft RF and SDR modules can be "dual use" with low-cost compact user terminals developed as a system, in parallel with the spacecraft development.

The C-Band Radio Spectrum

Let us begin by examining the amateur frequency allocations between 1 and 10 GHz in Table 1^{1,2}:

With AO-40's S-Band downlink, many amateurs have experienced serious QRM from unlicensed (Part 15) 2.4 GHz wireless devices including cordless telephones, 802.11b/g and Blue Tooth wireless LANs, in-home video monitors and microwave ovens.

These same wireless interests have expansion plans involving the 5-6 GHz C-band spectrum. 802.11a "WiFi" and 802.16 "WiMax" LAN devices and cordless telephones are already on the market. Can we, as amateurs, build a technology-based "brick wall" to protect these valuable frequencies? In Figure 1, we take a look at the 2004 view of the 5600-5900 MHz spectrum:

From this figure, we see that the 802.11a WiFi world has moved in to share the 5650-5670 MHz satellite uplink band. Let's make some estimates concerning the QRM situation that might exist at the satellite.

The WiFi definition calls for the use of CDMA techniques, with a maximum throughput of 54 Mb/sec (just like 802.11g on 2.4 GHz). The total bandwidth available to WiFi is 550 MHz (5150-5350 MHz and 5450-5800 MHz – the 5350-5450 MHz chunk is reserved for Radio Navigation).

- Let's assume that the WiFi users fill their allocation uniformly. The signals from the

many users will be noncoherent, so their signals add as wide-band noise.

- The population of the USA is 294 million, and Canada is 32 million. As a conservative estimate let's assume one C-band transmitter per person, operating 16 hours/day. This means that at any time there might be 217 million transmitters.
- Most 802.11a transmitters have low gain antennas and attenuation through trees and buildings would affect the signal seen at a satellite. So we assume that each transmitter transmits 1 mW EIRP. This means that the 217 million transmitters will be a noise-like 217 kW transmitter spread uniformly over 550 MHz, equivalent to $(217 \times 10^6 \text{ transmitters}) \times (1 \text{ mW/transmitter}) / (550 \text{ MHz}) = 0.39 \text{ mW/Hz}$ radiated
- The path loss from the earth to a HEO satellite at ~40,000 km distance is ~196 dB. Assume an earth-pointing spacecraft antenna gain of ~19 dB. A loss of 177 dB is equivalent to a factor of 2×10^{-18} .

Putting these numbers together:

$$(0.39 \text{ mW/Hz}) \times (2 \times 10^{-18} \text{ Path Loss}) = (7.8 \times 10^{-22} \text{ Watts/Hz}) \text{ at the input of the receiver.}$$

This worst-case power can be converted into an equivalent 802.11a noise temperature of

$$T_{802.11} = (7.8 \times 10^{-22} \text{ Watts/Hz}) / k = 57 \text{ }^{\circ}\text{K}$$

where k = Boltzman's Constant = $1.38 \times 10^{-23} \text{ W/Hz/}^{\circ}\text{K}$.

We will return to this topic later when we discuss system link performance.

Some Aspects of System Design

In the previous paper we outlined some possible design alternatives. In the last year we have refined our thinking on several topics, including:

HEO vs. LEO (Winner = HEO)

An attractive feature of C-C Rider for Low Earth Orbit (LEO) was the partial cancellation of Doppler with an inverting "bent-pipe" transponder, as well as the sharing of a single antenna for up- and down-link. Link budget calculations for the LEO case indicated the need for ~26 dBiC of antenna gain; this in turn necessitated antenna pointing accuracy of a few degrees while the satellite can move at angular speeds up to ~1/2°/sec. This seems to be a bit beyond the capability of the average amateur.

Table 1: United States Microwave Allocations

Amateur Service		Amateur-Satellite Service	
Band (MHz)	Bandwidth (MHz)	Band (MHz)	Bandwidth (MHz)
1240 - 1300	60	1260 - 1270 ↑	10
2300 - 2310	10	-	-
2390 - 2450	60	2400 - 2450	50
3300 - 3500	200	3400 - 3410	10
5650 - 5925	275	5650 - 5670 ↑ 5830 - 5850 ↓	20 20
10000 - 10500	500	10450 - 10500	50
24000 - 24250	250	24000 - 24050	50

↑ means Earth-to-space (uplink) direction only
↓ means space-to-Earth (downlink) direction only



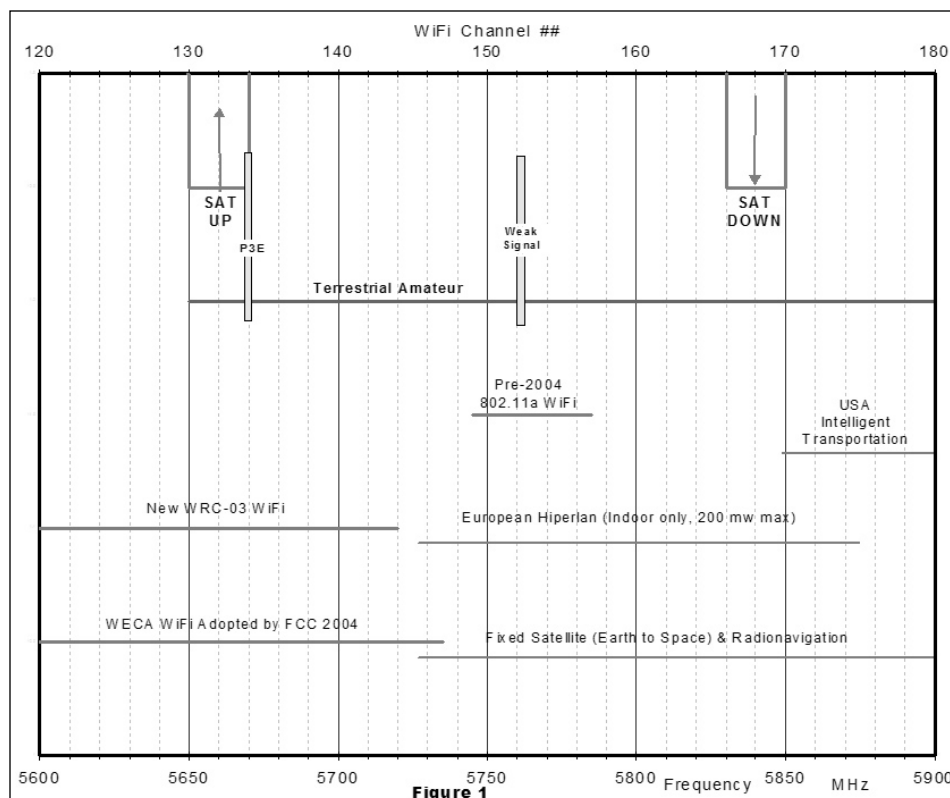


Figure 1

A High Earth Orbit (HEO) satellite offers the user a slow-moving target. Combining this with AMSAT's plans for the HEO Eagle satellite as it's next project led to our proposing C-C Rider as a main payload at the recent Eagle design meeting³. The concepts presented in the rest of this paper are the result of enthusiastic endorsement of the concept by all the developers present at the meeting.

The rest of this paper assumes a HEO Eagle mission with a perigee height ~1000 km and apogee height ~40,000 km.

"Bent-pipe" Transponder vs. Digital Regenerator (Winner = A New Idea!)

The previous paper described the simple "bent pipe" transponder implementation of the C-C Rider concept; this concept reproduced in Figure 2. Unfortunately, this simple scheme would not have worked well. If you examine it very carefully, you will see that the transmitter passband lies precisely on top of the image of the receiver passband. It would have been very difficult to achieve adequate image rejection, and the transmitter would have caused very poor receiver performance.

An addition to the concept was introduced in Figure 4 in the previous paper; this discussed the desirability of providing alternative digital "demod-remod" capability as has been espoused by Phil Karn.

As we prepared for the Orlando meeting, we developed an alternate implementation. The past two years have seen a revolution in Amateur Radio technique with the use of Software Defined Radios (SDRs). The receiver portion of an SDR is implemented by converting the desired RF signal to a convenient IF, and then digitizing the signal with an analog-to-digital converter (ADC). Final bandpass filters and signal processing is then accomplished in signal processing software. In this paper we will denote the receive side of an SDR as an SDRX.

The transmit function in an SDR is accomplished by generating the desired signal in software and then converting to analog with a digital-to-analog converter (DAC). This analog signal is then heterodyned up to the desired RF signal frequency. We adopt the notation SDTX for the transmit part of an SDR and SDX as the notation for the Software Defined Transponder.

In most amateur implementations to date, the ADC and DAC functions of the SDR have been implemented in a "Sound Blaster" sound card running in a consumer-grade PC. This includes all the audio baseband PSK31 implementations (like MixW) and real SDR's like LINRAD and SDR-1000. Sound Blaster performance limits these implementations to bandwidths < ~50 kHz.

Thus in Figure 3, we see the C-C Rider concept "morph" into the idea of the universal SDR-based transponder. To optimize performance, we see that all local oscillators (microwave and SDR) are all derived from a single low-noise master oscillator.

Let's think about a linear transponder implemented in SDR. The signal processor could:

- Remove gross Doppler offsets (less knob twiddling!)
- Apply suitable AGC to each individual signal (no alligators!)
- Optimize band utilization by suppressing unused parts of the band
- Allocate proper user vs. beacon power sharing

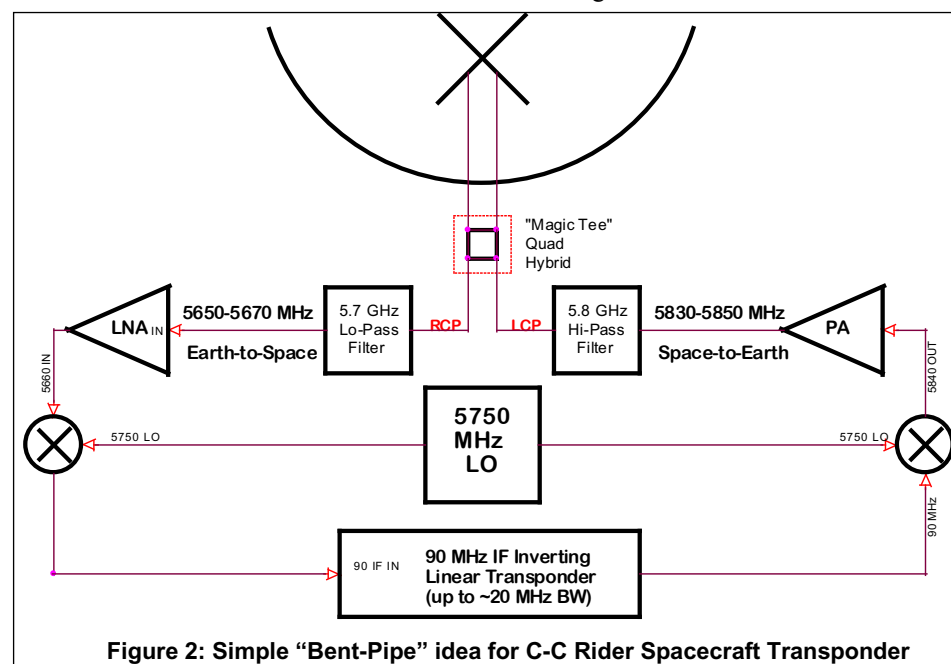


Figure 2: Simple "Bent-Pipe" idea for C-C Rider Spacecraft Transponder



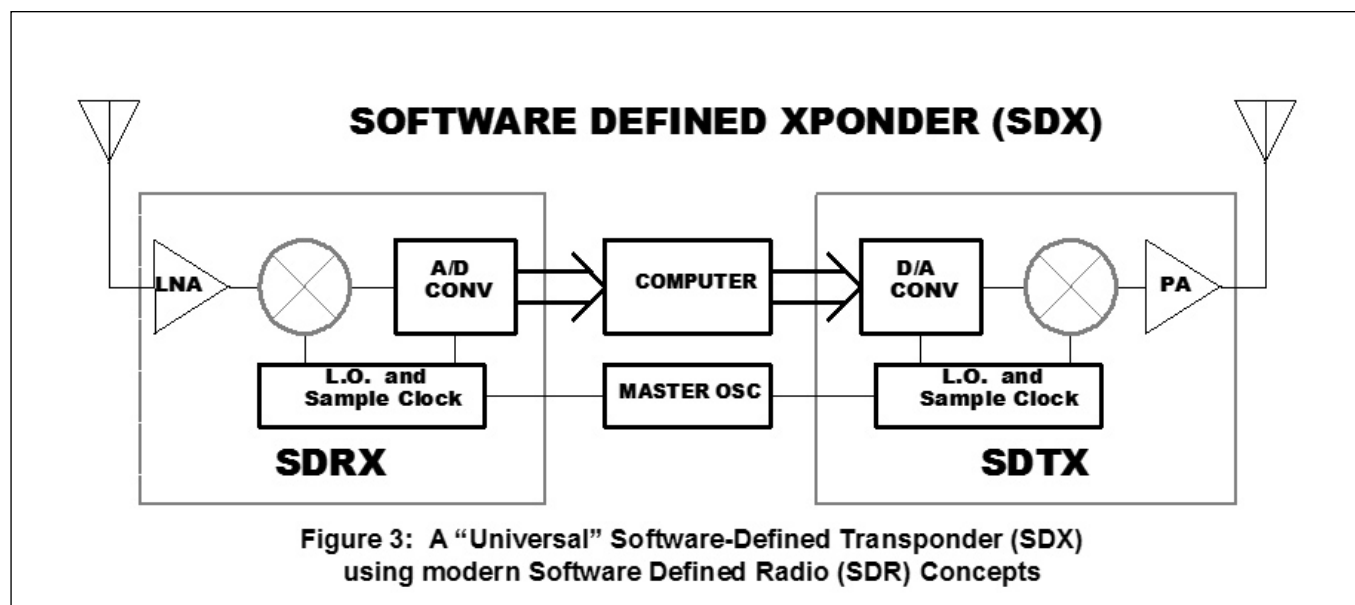


Figure 3: A "Universal" Software-Defined Transponder (SDX) using modern Software Defined Radio (SDR) Concepts

If a linear transponder was used for digital signals, the uplink and downlink Signal-to-Noise Ratios (SNRs) would be multiplied (making the link degrade as distance as $1/R^4$). Instead of taking this "hit", we would demodulate the digital signals at the spacecraft, applying error correction. The digital downlink signal would get "fresh" FEC coding added and the links perform as a pair of $1/R^2$ paths.

Dish Antenna vs. Array of Patch Antennas (Winner = An Array of Patches)

Last year's paper offered the two possibilities. At the Orlando EAGLE meeting it became apparent that an array of patches has a lot to offer. Dick Jansson, WD4FAB has prepared an extensive drawing package for the ~60 x

60 x 45 cm EAGLE satellite. In Figure 4 we begin with Dick's drawing of the EAGLE "antenna farm" which shows a large 70 cm patch antenna in one corner. On top of the 70 cm patch is an array of three patch antennas for the L-Band = 23 cm uplink. In diagonal corners are two separate arrays of four patches for use on S-Band = 13 cm.

As seen in this sketch, we fill the remaining area with an array of 36 circular polarized patch antennas for C-Band (5.7 GHz) on a 50 mm (one wavelength) grid. Each patch element would be a complete C-band micro-wave system as shown in Figure 5. This circuitry would be developed using modern microstrip development software (like Ansoft's HFSS package.⁴)

As mentioned in the first paper, each Power

Amplifier would be a $\frac{1}{2}$ - 1 watt output integrated amplifier designed for C-band wireless LAN use⁵. The LNA would be a low-noise PHEMT unit. The use of a distributed array of power amplifiers and microwave front-ends affords a unique level of redundancy. The failure of any one of the N elements would only degrade performance by a factor $1/N$.

Let's look at the operation of this array on the receive side first. In Figure 6 we show a ground-based beacon transmitter providing a pointing reference for the C-band system. In this example, Eagle's spin axis makes an angle α with respect to the signal from the beacon. Onboard the spacecraft, the signal from each of the antenna elements (after conversion to a convenient IF) is digitized in a separate SDRX channel⁶.

The phase data from pairs of SDRXs are combined to extract the phase difference Φ . As we see in Figure 7, the phase difference is related directly to the pointing offset α .

When projected onto the sky, the phase of the interferometer is periodic, with sinusoidal fringes that are spaced $2\pi B/\lambda$. The longer the baseline B, the finer is the scale of the interferometer fringes; but when B is more than one wavelength, the phase becomes ambiguous. The array sketched in Figure 4 has the patch antennas placed on a one-wavelength grid to avoid phase ambiguities, while the array has spacings as long as ~9 wavelengths to improve the accuracy of position determination.

We plan that the beacon signal will be strong enough so that the beacon's pointing angle can be easily determined. Then, knowing the

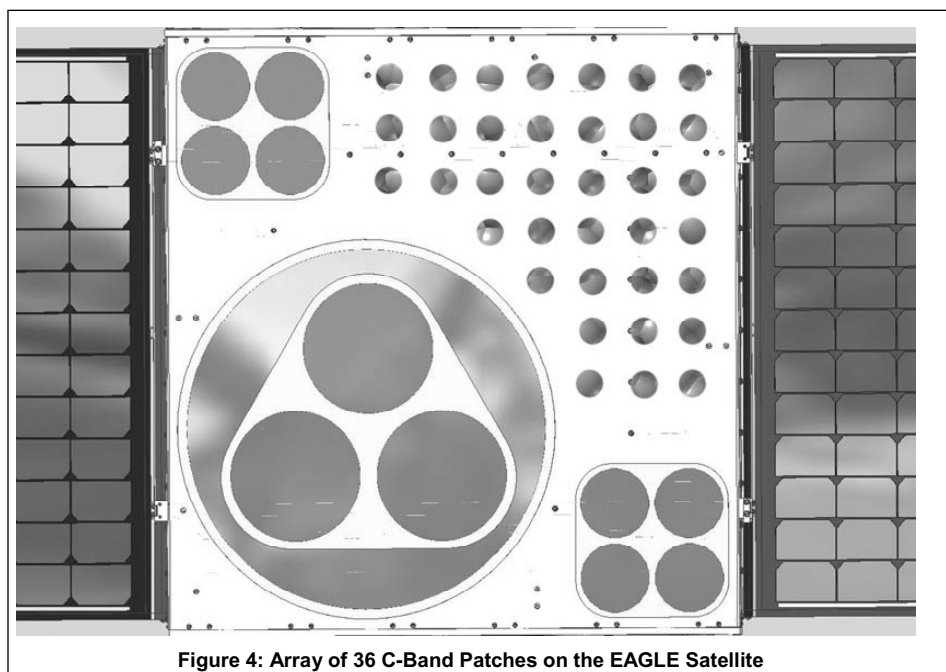


Figure 4: Array of 36 C-Band Patches on the EAGLE Satellite



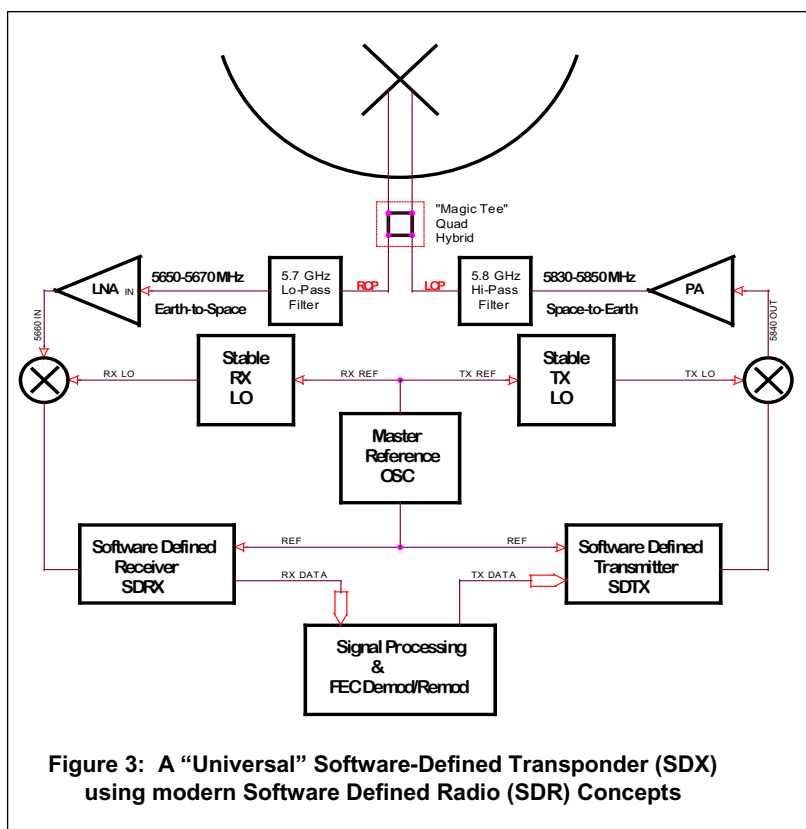


Figure 3: A "Universal" Software-Defined Transponder (SDX) using modern Software Defined Radio (SDR) Concepts

position of the earth relative to the spacecraft, the signals from all 36 antennas can be added to obtain a collecting area equivalent to ~30 cm dish. Since the array "pointing" is done electronically, the array can be slewed to point at the earth even when the spacecraft's spin vector is off-pointed. This in turn means that the spacecraft will be useful through a larger portion of the orbit.

Once the spin axis is located with respect to the beacon on the earth, the positional data can also be applied to the SDTX transmitter elements so that the transmitting gain is comparable to the receiving gain. The array shown in Figure 4 is a bit larger than is needed to fill the earth at a 40,000 km apogee. The excess can be used to "trim" the shape of the beam to better "light up" the limb of the earth, improving DX performance.

The gain of each individual patch antenna element should be ~5 to 6 dBiC. If the 36 element array is used on-axis, the arraying gain should be about $10 \times \log(36) = 15.6$ dB, the total gain should be in the 20 to 21 dBiC range, corresponding to a beamwidth ~19°. This nicely matches the size of the earth, 15.7° as seen from a 40,000 km altitude.

Some Estimates of Uplink Performance

To make estimates of the link performance for C-C Rider flying on Eagle, we make use

of an Excel spreadsheet developed by Jan King, W3GEY/VK4GEY7.

First, let's consider the uplink; the performance is critically dependent on the noise level that the spacecraft will see. Earlier we made an estimate that the worst-case noise contribution from 802.11a WLANs on the earth would be 57 °K. To this we add estimates of other contributions that we may experience:

Sky Noise

3 °K

This number can be increased if more robust

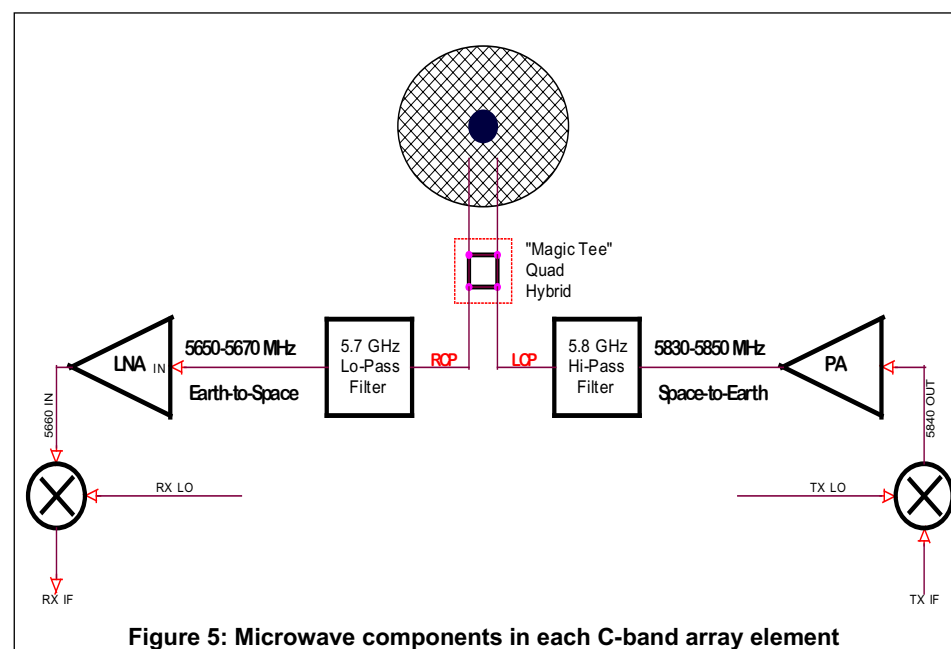


Figure 5: Microwave components in each C-band array element

LNA	40 °K
Antennas and Feedlines	50 °K
802.11a	< 57 °K
Transmitter (est.)	400 °K
TOTAL ESTIMATE	550 °K

The dominant term in this estimate is "Transmitter". To function as a transponder, the transmitter and receiver need to operate "full duplex" – receiving while transmitting. It is likely that each of the transmitter elements will generate some wideband noise that will be coupled into the receiver through the circular polarizing hybrid and antenna elements. Since the transmitter has not yet been developed, we can only flag this item as a serious worry!

To continue the uplink analysis, we note that we have an earth-to-space one-way path loss of -196 dB. If the user on the ground can develop 30 watts of power into a 20-21 dBiC gain antenna, his signal at the spacecraft will be about -129 dBm. If the spacecraft's antenna has a gain of 20 dBiC, the receiver will see a signal of about -109 dBm. Finally, if the receiver has a bandwidth of 100 kHz, this results in a S/N ratio of +12 dB.

If C-C Rider is used as a digital transponder that employs FEC, this performance implies a usable channel capacity in the 100-200 kb/sec range. Digital voice sounds very good with data rates of 10 kb/sec, so this link could support 10-20 noise-free voice channels. Each channel would support a two-way QSO or an n-way roundtable, so upwards of 50 simultaneous voice users can enjoy the Eagle/C-C Rider combination.



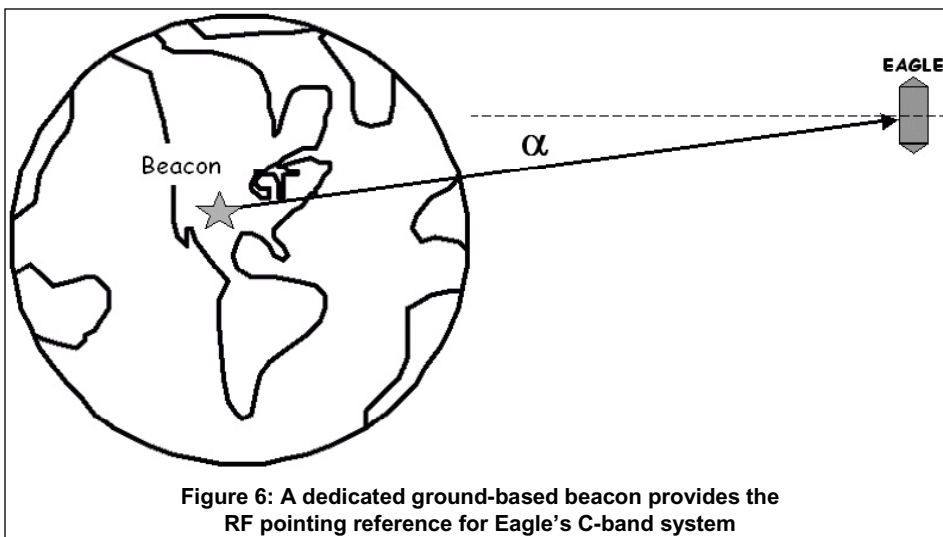


Figure 6: A dedicated ground-based beacon provides the RF pointing reference for Eagle's C-band system

uplinks can be developed. This might be done by

- Developing user terminals with transmitters bigger than 30 watts, or
- Developing user antenna systems with more than 20 dB gain, or
- Making the spacecraft transmitter have less noise in the uplink frequency band.

Estimates of Downlink Performance

Throughout the design we have assumed that the spacecraft and ground-based user terminals are nearly identical. Microwave hardware developed for the spacecraft could be re-used on the ground by merely swapping the TX and RX ports. The SDRX and SDTX software would be developed with a GNU-like Open Source model; while the actual computer hardware on the ground and in space may be different, much of the intellectual property investment is reused. Therefore it is quite likely that uplink and downlink system performance will be the same, with one major difference. The spacecraft needs to operate full-duplex, so TX noise leaking into the RX becomes a dominant noise contribution. But the user

will likely operate half-duplex, turning off the transmitter when not needed. The result is that the large TX noise contribution (estimated above to be 400°K) doesn't apply. But this may trade off against localized C-band noise sources (cordless phones, "sloppy 802.11a devices, etc.) in the downlink band. So, until we know a bit more about the 5830-5850 MHz spectrum, we assume that the downlink can support the uplink.

Some Concluding Comments

As Amateur Radio enters the 21st Century, we face significant pressure on our most important resource, *the Radio Spectrum*, especially in the 1-10 GHz range. Our allocations are precious to us, but we *will* lose them if we don't use them. And our usage needs to make significant contributions in advancing the state of the art.

AMSAT is now planning its next major satellite in the project that had been dubbed Eagle, which includes the C-C Rider concept discussed in this paper. We hope that it proves to be a challenging project that will inspire the participation of some new, talented people.

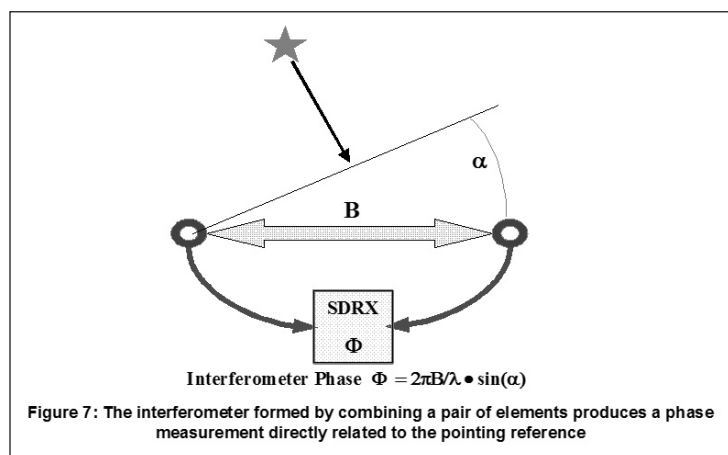


Figure 7: The interferometer formed by combining a pair of elements produces a phase measurement directly related to the pointing reference

The ideas expressed here are far from final. Here are some areas that can challenge new blood:

- Can we really cram a one-watt C-Band PA, patch antenna, circular polarization combiner, bandpass filters and LNA into the 50 mm (~2 inch)

space shown in figure 4? What DC-to-RF power efficiency will we be able to achieve? How do we get rid of the heat that doesn't make its way into RF energy?

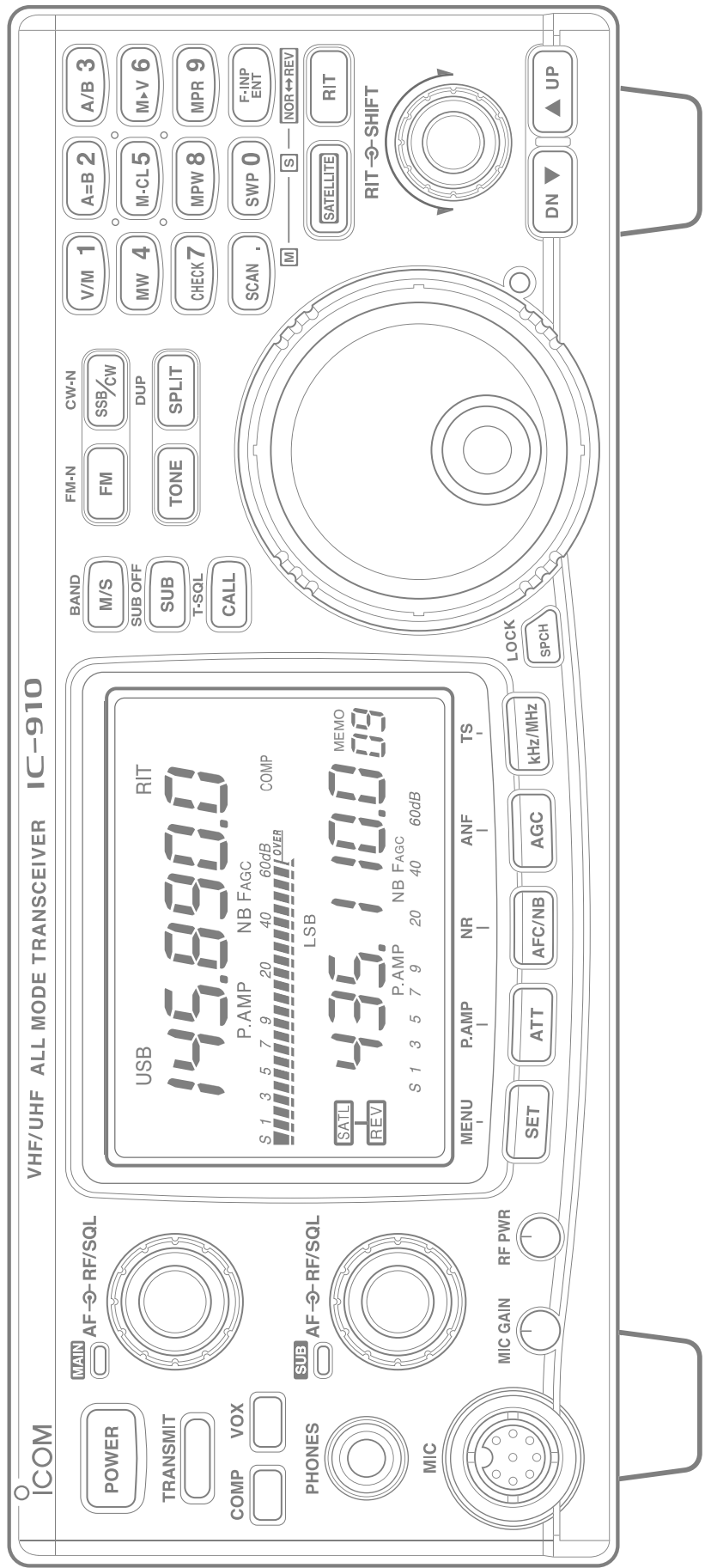
- How quiet will the TX be in the RX band? Link performance is critically dependent on this.
- How much will these modules weigh? Will they upset the spacecraft's 3-axis moment of inertia that allows the satellite to spin smoothly?
- The design of the multi-channel SDRX and SDTX will be challenging! How much computing horsepower is needed? What's the mix between general purpose CPUs vs. DSP CPUs vs. Programmable Gate Arrays?
- What communication protocols will we use (Time slotted TDMA? CDMA? FDMA?) What is the ratio of Error Correction bits to Data Bits?
- How much power is needed? How much heat will be generated? What temperature range can be tolerated by the hardware?
- How do raise enough money to fund the development of the payload, the Eagle satellite and the launch? Can we find (and afford) a suitable launch?

The way for you to become involved is to volunteer. AMSAT is an Equal Opportunity Exploiter!

Footnotes

1. See W3IWI's paper in AMSAT Space Symposium, 2003 Proceedings, also reprinted in *The AMSAT Journal*, August 2004.
2. Thanks to Paul Rinaldo, W4RI, for supplying an early version of this table.
3. Held in Orlando, Florida in July 2004.
4. See <http://www.ansoft.com/products/hf/hfss/>.
5. For one possibility, see http://www.hittite.com/product_info/product_specs/amplifiers/hmc408lp3.pdf. Initial tests on this amplifier in August 2005 show that it will perform well, providing we can design an adequate way to dissipate the heat generated by the amplifier.
6. Lest you become too concerned with the complexity of this operation, realize that your typical 12-channel handheld GPS receiver contains a separate SDRX for each of the 12 channels!
7. Available at http://www.amsat.org/amsat/ftp/software/spreadsheet/AMSAT-IARU_Link_Budget_Rev1.xls 📎





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Accessories

- AG-2400**
Downlink Receive Converter
Converts a 2400MHz RF signal to a 144MHz IF signal, allowing US mode operation. Use with optional UX-910, for LS mode operation.
- AG-25** 144MHz
AG-35 430MHz
Preamplifiers
External all-weather, mast mounting preamplifiers. Compensates for cable loss.

- UT-106**
DSP Unit
AF-DSP functions, including noise reduction and automatic notch filter. Use two, one for main band & one for sub-band.
- UX-910**
1200MHz Band Unit
Turns the IC-910H into an all mode, tri-band transceiver. Also makes crossband and full duplex operation possible.

